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ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors are printed in *italics*.

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THE SHUT-OFF DAM AT THE CHARLES RIVER BASIN.

BY JAMES W. ROLLINS, JR., MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, September 15, 1909.]

I DO not suppose there is any one man in this Commonwealth who has dammed the Charles River as many times as I have. For ten years we have been at work on this river, on the West Boston Bridge and the Charles River dam and embankment, and in this time we have very often dammed the river because the tide came too high or not high enough, too low or not low enough; so when the problem arose of making a real dam, we tackled the proposition with a good lot of experience behind us.

In every proposition of building a dam the most difficult problem outside of the cofferdams is how to handle the flow of the river or tide in the final closure of the cofferdam, which will first raise the water level to its proposed new grade. Generally a canal opening, being built first, will handle the regular flow, and then the permanent structure is built out from both sides behind cofferdams to the extent possible, considering the minimum water way to be left open for final closure. A customary way of making this final closure is to float a crib into the gap and sink it into place with stones, then by sheeting or earth fill making it water tight. This crib in, the final gap in the main dam can then be closed.

The history of the Charles River dam has many times been written, and many reports of the scheme have been made, and

this society has listened to an able paper on the subject by the chief engineer of the Charles River Basin Commission, so I will not go into any historical matters. The first report mentioning the matter of the shut-off is that of the Joint Board upon the improvement of the Charles River, in 1894, in which the question is briefly handled in these words:

"The most difficult problem to solve in connection with the construction of the dam is the shutting off of the flow of tidewater into and out of the basin. The quantity of water which must pass the location of the dam as long as the tide rises and falls in the basin is very large, and although it now passes this location without causing any disturbance, the currents will continue to increase in strength as the dam is built up and the area through which the water can pass becomes more and more restricted. The order in which the work should be constructed, and the character of the temporary works for shutting off the water, have been carefully studied, and there is no doubt but that the work can be successfully accomplished.

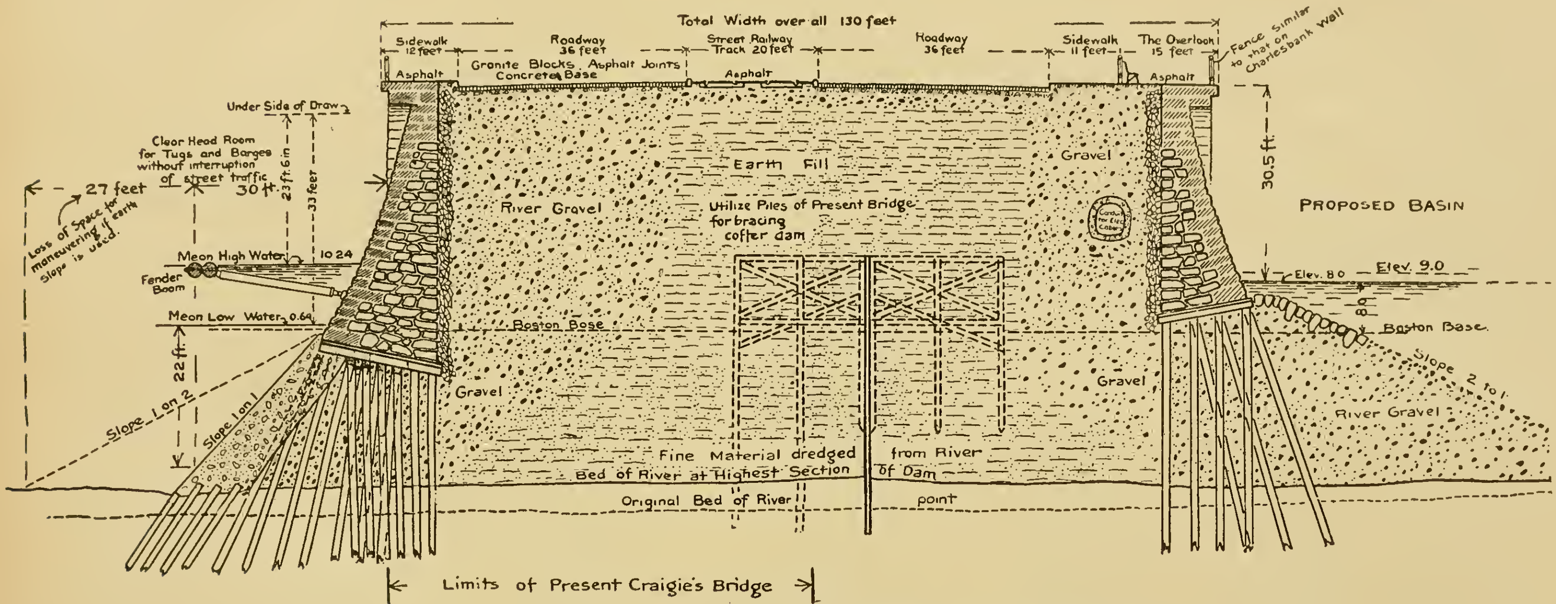
"It is found that after building the lock and leaving it open for the passage of water it will be feasible to dump earth for forming the embankment of the dam until it is brought up nearly to the level of low tide. Upon this embankment, as a foundation, temporary works can be constructed which can be closed during a single tide, and thus form an effective temporary dam. By means of the lock, the water in the basin can be kept at such height as may be found most desirable until the completion of the dam."

The first sketch, showing a shut-off dam in the various reports on the Charles River project, is taken from the report of John R. Freeman made in 1903. (Fig. 1.)

I presume this plan is presented as a sketch only, and is shown midway of the dam section, which is a high, narrow dam, about the width of the proposed new highway only. As far as the writer can learn, this sketch was the basis of the final contract plan of the shut-off dam as presented by the Charles River Basin Commission. (Fig. 2.)

This plan shows four vertical piles, specified to be of yellow pine, 12 in. in diameter 3 ft. from the butt, and 6 in. at the tip, all under the bark, with bracing of 3 in. by 8 in. spruce fastened by $\frac{3}{4}$ in. bolts. In addition there were two guide piles, 8 in. by 12 in., which, however, were not to be driven into the original river bottom.

A study of this plan shows its impracticability and its weakness. The absence of any spur piles throws all the strain of the water pressure on the very light bracing, which bracing has no



TYPICAL SECTION AT MAXIMUM HEIGHT
PROPOSED CHARLES RIVER DAM

STUDY B - FOR HIGH DAM WITH SOLID FILLING

PERMITTING PASSAGE OF TUGS AND BARGES WITHOUT OPENING THE DRAW BRIDGE

FIG. 1.

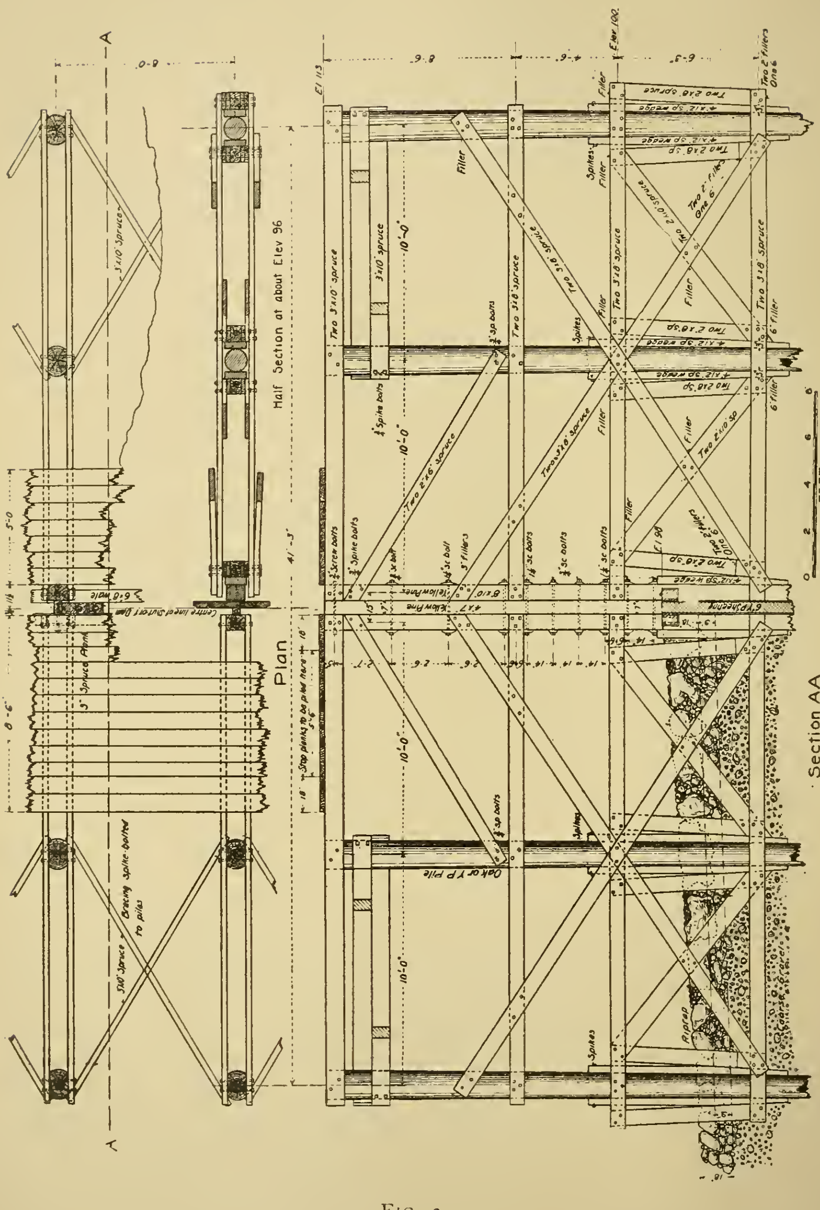


FIG. 2.

direct fastenings through the piles at the lower end of the horizontal braces, which are 6 ft. below low water, but depends solely upon very fine wedges to make a tight connection. It is evident that too hard a blow on these fine wedges would tear away the outside connection of 3 in. by 8 in. spruce and $\frac{3}{4}$ in. bolts, these bolts passing through two 3 in. by 8 in. spruce braces with five fillers between. The engineers expected that these braces could be put on by divers, or fastened together, then lowered into place and wedged up. This latter plan would require absolutely straight piles, free from knots or other irregularities, and also require that the piles in bents be driven true to line. Further, the depositing of the riprap, consisting of stones up to two tons in weight, would, in all probability, break many of the 3 in. by 8 in. spruce braces or their poor connections, especially at the outside ends of the lower bracing.

Further, the method of fastening the top of the low sheeting after it had been sawed off was an impossibility, as the short walings at grade 98 could not be inserted into the steel castings unless the entire line of sheeting between the castings was exactly true, with no wind in a single piece. As there was to be no waling on this line of sheeting above low water, there was nothing to prevent the twisting or getting out of line of this sheeting after the top temporary wales were taken off.

Again, a set of very light diagonal bracing, 3 in. by 10 in., was shown on the tops of the piles, which prevented the depositing of the sand, gravel or riprap between the bents.

This plan contemplated the making of the final closure by means of a series of stop-planks inserted into the built-up groove in the 8 in. by 12 in. vertical piles, these piles being 8 ft. from center to center. There were to be 102 spaces, 16 stop-planks for each opening, and they were to be handled according to the contract as follows:

"The contractor will be required to put all the stop-planks in place between the first and second of four consecutive high neap tides, none of whose predicted heights, as shown by the tide tables of the United States Department of Commerce and Labor, are more than 9.5 ft. above mean low tide, and when, in the opinion of the engineer, the wind and weather are favorable. He shall begin placing the stop-planks a short time before low tide when directed and shall have all the planks below the level of the water in place before the tide begins to run upstream at the dam, and shall place the remainder of the planks in season to prevent any overflow at the dam. Previous to placing the stop-planks, he will be required to organize a force which, in the opinion of the

engineer, shall be of sufficient size and sufficiently trained to insure the placing of the stop-planks in the times above stated. The work shall in all its details be carried on in accordance with the instructions of the engineer. If the contractor shall have placed the stop-planks properly in the times above stated, the commonwealth shall be responsible for any failure of the shut-off dam to withstand the pressure of the first two high tides which come against it, but should it fail subsequently, the contractor shall be responsible. No allowance shall be made the contractor for any delays which may occur by reasons of the provisions of this section or the requirements of the engineer thereunder."

To do this trick right would have required a large force of men and much luck to avoid getting some planks jammed and fouled in the bustle of the final act.

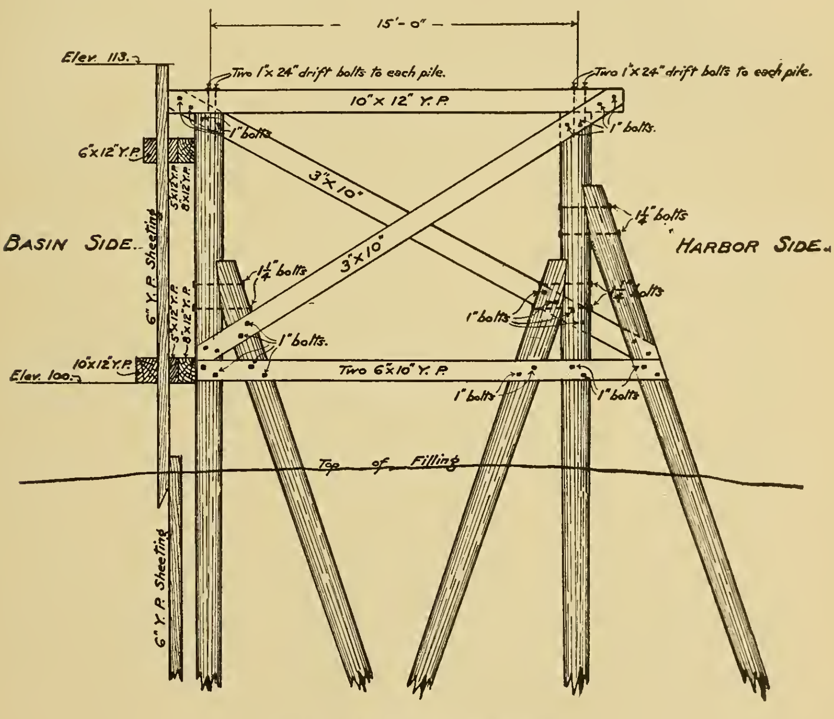
The contract shut-off dam extended from the masonry of the lock to the masonry of the sluices, and required the removal of the great, solid and settled cofferdams around these two structures, exposing them and their pile foundations to the flow of the tide, and especially, in our opinion, endangering the lower corner of the lock foundation, which was above the original bottom of the river and filled to the top of the piles with gravel. This corner was the most exposed point on the whole job, as the tide swirled around it into the main channel, and it required special extra planking in the fill outside the main cofferdam to protect the slope.

You will note the conditions: Using a contract plan, giving all details; doing the work of construction in detail as directed by the engineer, with a guarantee, on the part of the commonwealth, of the structure so built for forty-eight hours only; all damage or loss after that time, even if everything has been done in full accordance with instructions of the engineer, to fall on the contractor.

Luckily for us, the shut-off dam did not come up for consideration until two years after beginning the job, and during this period we had time to study and consider every detail of the contract plan, and with the result that from a practicable standpoint the above-described weaknesses were developed.

We further doubted the theoretical strength of the structure to meet the conditions, imposed by the engineers, of holding the water in the basin at grade 108 with the tide outside at 100, or the tide in the river at 110 and the water level in the basin at grade 104. To settle this point of theoretical strength we referred the question to three eminent consulting engineers, and they agreed upon the fact that to meet the conditions imposed by

the dam engineers would allow only a factor of safety of $1\frac{1}{2}$ or 2 under the best conditions, assuming that the braces and fastenings at the lower ends were in perfect condition, but if any one of these joints failed, that bent would surely collapse. One of our engineers reported: "This plan is a structural impossibility." And as we considered it a practicable impossibility we at once wrote the commission, stating to them our feelings and beliefs, and declined to build the structure unless we were relieved of all responsibility. At the same time, we submitted to the commis-



Bents 8 feet centre to centre.

FIG. 3.

sion a plan designed by our engineers which was much simpler, with a factor of safety of 4 on the commission's prescribed conditions, we guaranteeing the dam, and estimating its cost, at our contract prices, at $14 000 less than their plan. This plan (Fig. 3) proposed cutting the sheeting at grade 97, a foot lower than the commission's plan, and shortening its length to the outside of cofferdams at lock and sluices a length of 655 ft., as against 820 ft. in the commission's plan. This plan relieved us of removing

the cofferdams, which meant 50 000 yd. of material and 500 ft. of solidly bolted and braced wooden structure in the cofferdams.

After much discussion the whole matter of the design of a suitable shut-off dam was referred to Mr. George B. Francis, our honored president, and with his great practical experience behind him he soon devised a structure which satisfied everybody.

This plan (Fig. 4), with the addition of two vertical piles in the center of the bent on either side, was the plan under which the shut-off dam was finally and most successfully constructed.

This plan called for a double bent, each with three vertical piles and two spurs, with very heavy cross-bracing, heavily bolted, and the lowest braces above the low water line; a perfectly simple structure, of great strength, easy to build and to build well, as all its parts and connections could be seen and properly made. The main sheeting in the center between the two bents was driven through temporary wales to about elevation 103 at the top. Two 8-in. by 12-in. horizontal wales were then bolted on by divers at grade 96.5, and when secured the temporary wales were taken off and the sheeting cut off by a floating saw machine at elevation 97. Two 8-in. by 12-in. posts, with a 4-in. by 7-in. spacer between them, forming a groove in which the gates slid, were then set up on the low wales and securely bolted to the inside piles in each bent. Between these posts the gates were built, about 8 ft. in width and 16 ft. high, of 6-in. hard pine sheeting splined together, the timber being horizontal. The gates were suspended by ropes from a cap of 12-in. by 12-in. hard pine resting on top of the gate posts.

The construction of the shut-off dam was easily and quickly accomplished. With the exception of about 100 ft. in the channel the bents were built singly, so that the sheeting could be cut off with a floating machine, but in the channel where the sheeting had to hold the full depth of the tide as soon as the last plank was driven, the whole pile structure was completed before the sheeting in the closure was driven. This closure was the only exciting part of the work, for if not all driven down at low tide the pieces not driven would be subject to great pressure and very swift currents. The timber was carefully measured to close the gap, all walings bolted in place, then a little before low water two picked crews went at the driving. The planks were driven through two lines of temporary wales, the top set at about grade 110. When the sheeting was driven to this grade this line of walings had to be taken off in order to drive the sheeting down. An extra gang of carpenters did this work, so that the pile-drivers were not

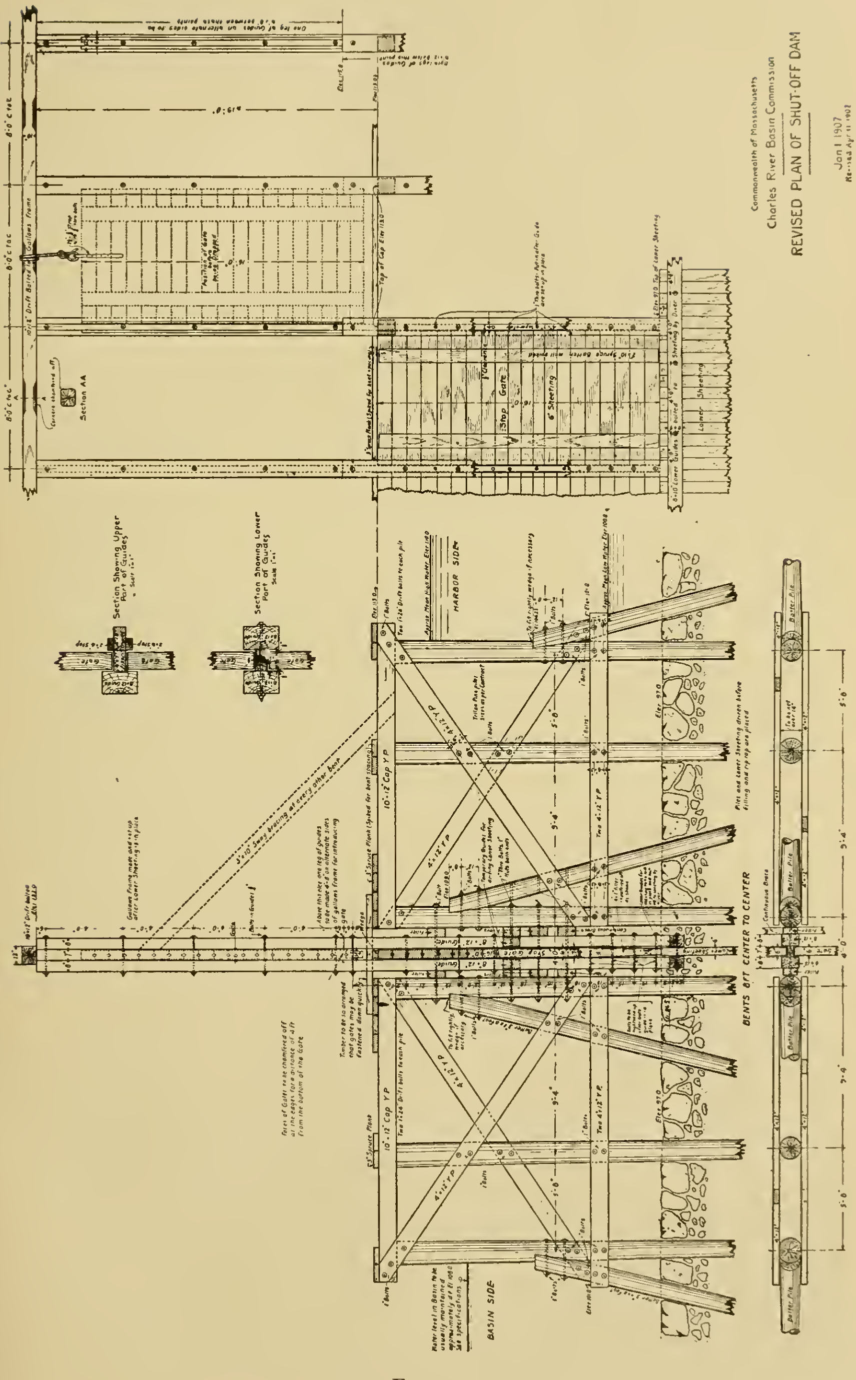

Commonwealth of Massachusetts
Charles River Basin Commission
REVISED PLAN OF SHUT-OFF DAM
Jan 1 1907
Section AA
Section Showing Upper Part of Guides
Section Showing Lower Part of Guides
HARBOR SIDE
BASIN SIDE
Stop Gate
6" Sheeting
Lower Sheeting
10"·12" Cap Y.P.
BENTS 8FT CENTER TO CENTER

FIG. 4.

delayed, and all working together got the entire length of the closure down to the low wales in 1 hr. and 40 min. On this section the wales at elevation 96.5 were left off and a permanent line at 102 left on, the sheeting being here cut off at elevation 102.5. After the sheeting was driven and cut off the sand and gravel fill was placed to proper grade and the riprap placed on the top. At times of spring tide the current over the crest of the shut-off was very swift and caused much trouble to the vessels bringing the riprap, as the boats could not be moved while the tide was running, and at low tide the boats grounded on the outside edge of the deposited stone, in some cases to the extent of almost wrecking them.

The date of October 20, 1908, was selected as the day of making the shut-off, the tide being low at 2.00 P.M. at grade 101.4. We planned to drop the gates when the tide was at about grade 105, which was figured to be at 10 A.M.

As this "shut-off" marked to a certain extent the completion of the work it was decided by the commission to make an event of it, and consequently many persons of note in the state and the cities of Boston and Cambridge were invited to be present, the governor of the Commonwealth, the Hon. Curtis Guild, Jr., being the guest of honor. To make "the act" interesting it was arranged to drop all the gates at a given signal, — a whistle blown by the governor.

October 20 dawned cold, gray and gloomy, with a heavy east wind, just what we did not want, but what we could not help. The day previous all the gates had been tried and lowered to their seats and all worked perfectly. Experiments showed that even with the water at grade 108 the gates would drop to their seats, so we did not fear to drop them at any lower grade. The gates were all hung to the caps with 1¼-in. manila rope, on one single rope.

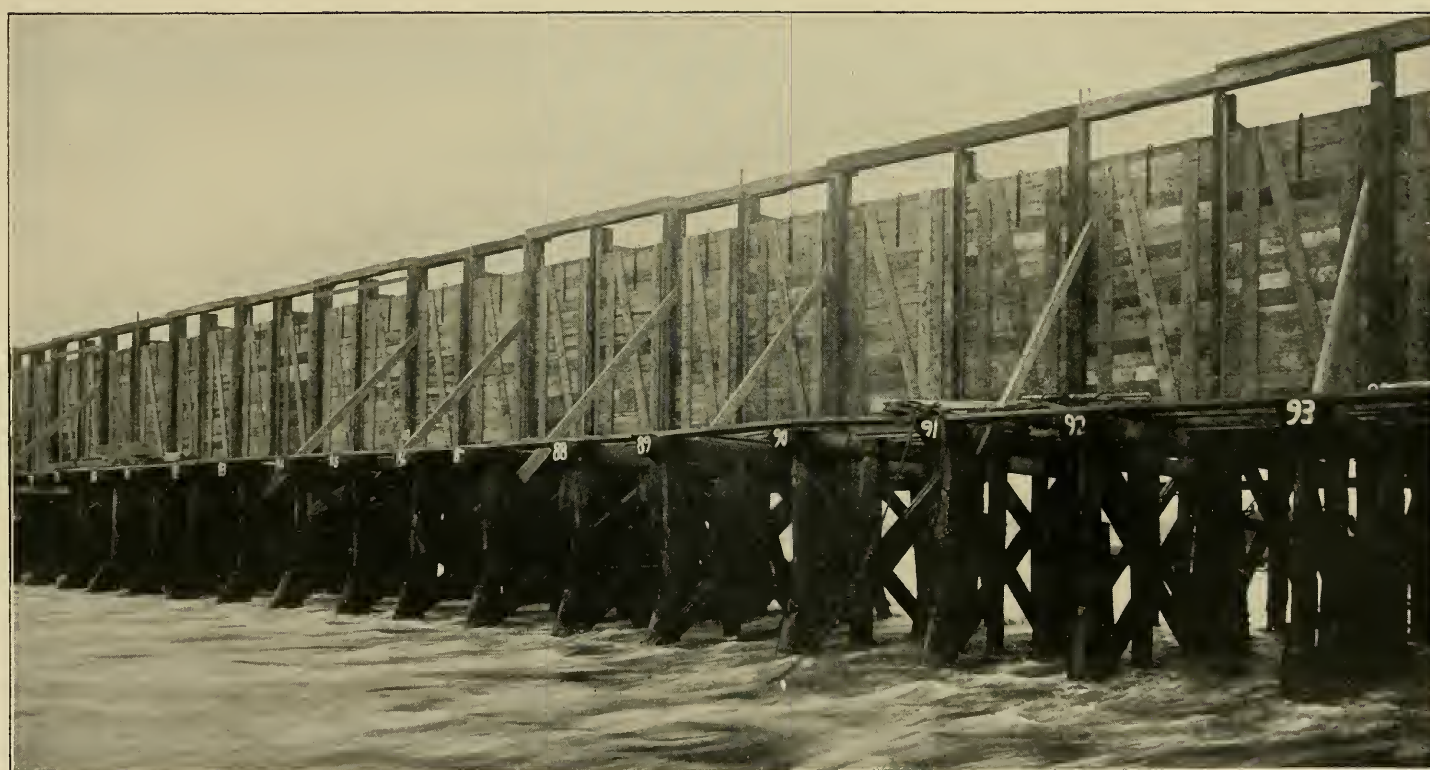
At 10 A.M. the crowd came, but the tide did not go down, on account of the east wind. Finally, after a long wait, it was decided to drop the gates at 11 o'clock, and the governor was sent for, arriving at 10.55. Meanwhile, forty men with sharp axes were stationed along the top of the gate posts on a staging, each having his instruction to cut two ropes, one on each side of him, at the blast of the signal whistle.

Exactly at eleven the governor pulled the cord, the whistle blew, forty men struck for their ropes, and in 7 seconds the gates had dropped, while the crowd cheered and the whistles blew. It was a moment of personal satisfaction to the writer calling

General View of the Shut-Off Dam from Boston Side before Gates were Closed.

Top of Lower Sheeting, showing Wales, Braces, etc.

Detail of Pile Trestle, Guide for Gate, etc.



Down-Stream Side of Shut-Off Dam. Water Elevation 102.

Dropping the Gates at the Shut-Off Dam.

"time" to the governor, who gave the signal which would stop that mighty tide which for years had defied everybody, going and coming as it willed, but now forevermore at rest at man's command. It does not often fall to the lot of man to so control in a few seconds the force of nature, and that force one which had for all time its own way, to man's trouble and loss, as probably equally to his profit and enjoyment.

The gates dropped, the men on top quickly descended and wedged and fastened the gates down hard on their bearings. This done, the uprights were sawed off close to the deck of the structure, and the dredgers began piling the earth on both sides. The water in the basin was at grade 106.5 when the dam was closed, so we had considerably more pressure downstream than we had anticipated. But no sign of movement was noted in any part of the structure at any time after the closing.

As a few statistics, I give the main items of material: 34 824 lin. ft. round piles; 360 000 ft. B. M. lumber; 60 800 lb. iron; 10 000 tons riprap.

Length of dam, 655 ft.; cost, $48 000.

The final plan was designed by Mr. George B. Francis, and modified slightly by the Charles River Basin Commission, Mr. Hiram A. Miller, chief engineer. The work was done under the direction of Mr. John L. Howard, resident engineer, and Mr. J. Albert Holmes, assistant engineer, of the commission; but the men to whom most credit is due for the construction and successful final operation are Samuel Taylor, inspector for the commission; and Fred Logan, foreman carpenter for the contractor, the Holbrook, Cabot & Rollins Corporation.

DISCUSSION.

Mr. Harold P. Farrington. — In an investigation of a structure of this kind it is necessary to make certain assumptions. Some of these we know are more or less erroneous, and conclusions should be modified accordingly. The truth of others cannot be entirely relied upon even under the most favorable conditions, and circumstances over which we have no control may alter them completely. In the following computations each assumption will be stated, together with the effect on the structure if it is not correct.

The computations are based upon an assumed head of 8.5 ft., with the following elevations of water: Downstream, elevation 110.5; upstream, elevation 102.

Referring to Fig. 2 it may be seen that the wales at the top

of the sheeting are fastened to the main shut-off guides. The computations assume the two to be independent of each other. If any of the pressure brought to bear on the guides is resisted by the sheeting, the safety of the structure is increased, and *vice versa*.

The guides form a continuous beam over the supports 1, 2, 3, 4 and 5. (Fig. 5.) The error will be comparatively small, and the method of computation practically as well suited to the problem, if we assume the pressure between any two supports to be distributed as though the guides acted as a simple beam between these supports.

Figuring on this basis, the distribution of pressure at the joints is as follows: (1) 580 lb.; (2) 5 090 lb.; (3) 12 050 lb.;

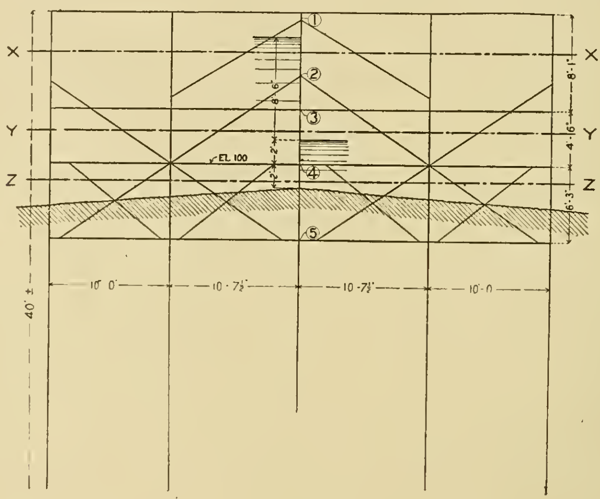


FIG. 5.

(4) 16 790 lb.; (5) 1 400 lb. Total, 35 910 lb. This indicates the maximum load to occur at joint (4), (Fig. 6), at which point the average stress transmitted per bolt is 2 800 lb. While this appears to be high, indeterminate factors enter into the problem which would undoubtedly reduce this stress before failure could occur. The continuity of the guides would transfer some of the load at (4) to other joints. Also, one or two of the stop-planks would possibly bear directly against the braces. The fact that the wales at the top of the sheeting are fastened to the guides might either increase or decrease the stress transmitted by the bolts.

The computed shears on sections indicated on Fig. 5 are the following: Section Y–Y, 17 720 lb.; Section Z–Z, 34 510 lb. The

shearing stress on Section Z–Z is carried by the diagonals and bottom wales to the filler blocks which bear, through the wedges, on the piles. (Fig. 7, which shows Section W–W.) Evidently this entire stress must be transmitted by one half the bolts passing through the bottom joints. The average stress transmitted per bolt is 2 970 lb. The shear on Section Z–Z, and all

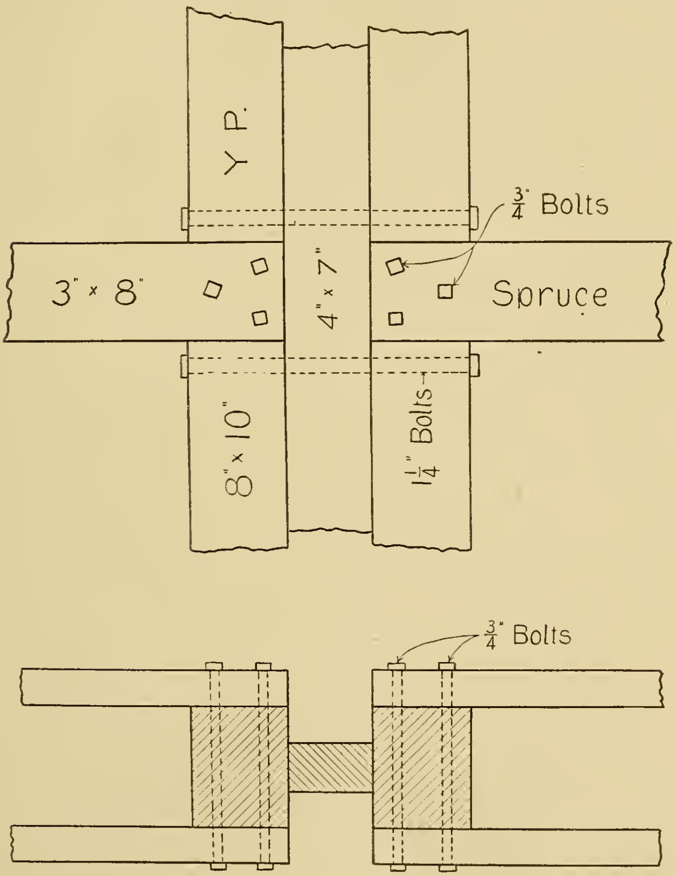


Fig. 6.

stresses dependent on this shear, are probably somewhat less than computed, because of the relative elevation of the riprap.

The computation of the bending moment in the piles at the bottom wales depends entirely upon the assumptions made in regard to the distribution of pressure on the piles. The section (Fig. 2) shows the mean depth of filling over the bottom wales to be $3\frac{1}{2}$ ft. A 40-ft. pile would extend about 21 ft. below the bottom

wales. Assuming one third of the total pressure on the piles to come above the bottom wales, and the line of action of the other two thirds to be 5 ft. below these wales, the resulting fiber stress in the pile is about 2 900 lb. per square inch. Assuming one half the pressure to be above the wales and the line of

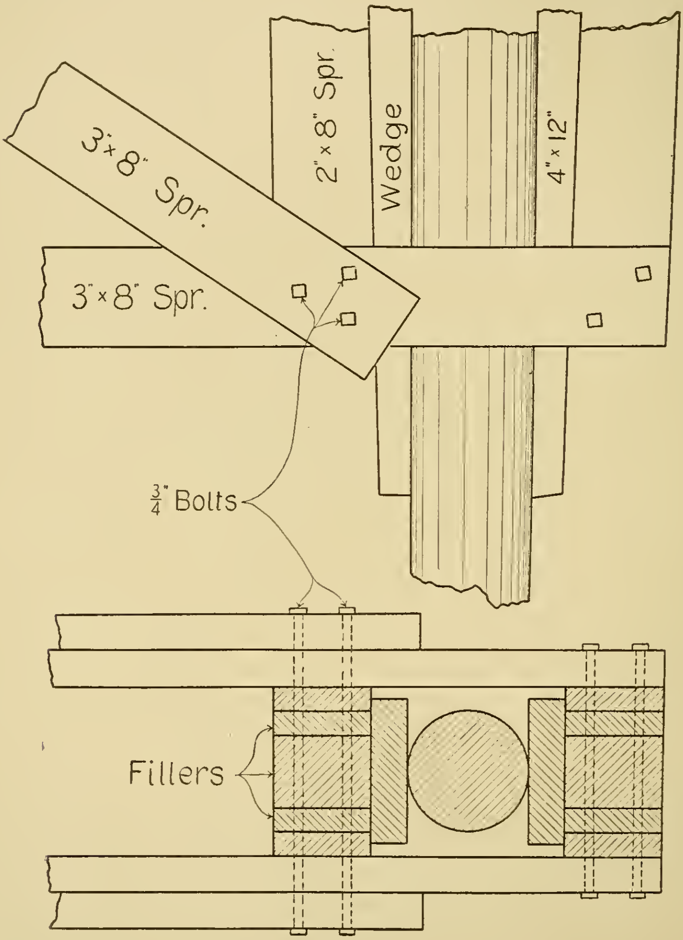


Fig. 7.

action of the other half to be 3 ft. below them, the resulting fiber stress is about 1 300 lb. per square inch. The second assumption may be more nearly correct; nevertheless the first assumption might be reasonable. While the above computations are based upon a regular spacing of the bents of 8 ft. center to center, it is

quite probable that, due to irregularity in driving the piles, the pressure resisted by certain bents would exceed the average by as much as 10 per cent.

In closing, emphasis is laid again on the uncertainties which make an exact solution of a problem of this nature impossible.

Mr. Frederic H. Fay. — At the request of Mr. J. W. Rollins, Jr., the speaker, in 1906, investigated the strength of the design for the shut-off dam proposed by the Charles River Basin Commission (Fig. 2) and that of the design proposed by the Holbrook, Cabot & Rollins Corporation (Fig. 3) under different assumptions of water level in the basin and harbor, the worst condition taken being with the water in the basin at elevation 108, and in the harbor at elevation 100, giving 8 ft. head on the shut-off dam.

Charles River Basin Commission's Design. — The commission's design, shown in Fig. 2, has been described by Mr. Rollins. The structure can be stable only if the water pressure on the stop-planks, which are held between two 8-in. by 10-in. vertical guide timbers at the middle of each bent, is largely distributed, by means of the cross bracing, over the four vertical piles; and in the absence of any inclined or batter piles, the entire lateral water pressure must be resisted by the bending of the vertical piles and guide timbers. The design required sand and gravel filling to be carried to elevation 93, above which was to be deposited a layer of coarse gravel. The latter was to be paved with riprap whose surface should slope each way from about elevation 98 at the middle of each bent to about elevation 96½ at the outer piles of the dam. It was assumed that before the shut-off dam was put into service, the filling and riprap would become compacted so as to offer considerable resistance to the lateral movement of the dam, and the probable plane of rupture of the piles and guide timbers under lateral pressure was taken at elevation 94.

The speaker was well aware of the great difficulty of constructing the shut-off dam according to the commission's design, and the likelihood that the cross-bracing would be seriously damaged by the depositing of the filling and riprap; nevertheless, he began this study of the design on the assumption that the cross bracing would be in perfect condition when the structure was put into service. Considering first the two 8-in. by 10-in. vertical guide timbers, calculations showed what was obviously true, that, although these timbers were well bolted together, they were wholly insufficient in themselves to withstand the entire

water pressure, and reliance would have to be placed upon the cross bracing to distribute most of this pressure to the vertical piles.

Attention being directed to the cross bracing, it was found that the stresses which this bracing could carry were limited by the strength of the bolted connections, which in general can transmit to the bracing timbers only a fraction of the total stresses which the timbers themselves would be capable of resisting. The connections are made with $\frac{3}{4}$ in. diameter bolts, two or three being used at each joint; and in some instances filler blocks are used between the cross braces and the piles or guide timbers. The strength of each joint was calculated by taking account of the bending of the bolts and their bearing against the timber. In all cases the strength of the connection is the strength of the $\frac{3}{4}$ in. bolts in bending, and in cases where fillers are used the leverage in bending is so large that the connection has little value. Allowable stresses were next assigned to the several braces proportional to the strength of their respective connections, and the resultant bending on the vertical piles calculated.

The specifications for the piles of the shut-off dam required them to be not less than 12 in. in diameter, 3 ft. from the butt and not less than 6 in. in diameter at the small end; and, according to the geological profile shown on the contract plans, the bottoms of the piles when driven would range from about elevation 75 to elevation 62. Assuming the piles to have a uniform taper, the diameter of the piles at the assumed plane of rupture at elevation 94 would be between 9 in. and 10 in. There is nothing in the specifications to prevent the use of piles having a smaller diameter at this point, but in calculating the strength of the piles in bending it was assumed that the diameter at the point of rupture would be at least 9 in.

Mr. Rollins has called attention to the fact that at the bottom of the system of bracing, which extends some 6 ft. below low water, the diagonal braces are not bolted to the piles and can communicate their stress to the latter only by means of finely adjusted wedges. It is believed that, in practice, the driving of these wedges would put a considerable amount of initial stress into the diagonal bracing, particularly into the short diagonals below elevation 100; and for this reason the speaker is of the opinion that it would not be safe to count upon any strength in the diagonal bracing below that elevation, even assuming it to be entirely uninjured by the depositing of filling and riprap.

Briefly, the results of the speaker's investigation of the

strength of the commission's design for the shut-off dam are these: Assuming the bracing to be uninjured by the depositing of the filling and riprap, that all braces act up to the full value of their connections and that none of them receives initial stress by the driving of the bottom wedges (in other words, a perfect structure), the design shown is found to have a factor of safety of about 2 with water in the basin at elevation 108 and that in the harbor at elevation 100. If no reliance be placed upon the strength of the diagonal bracing below elevation 100, owing to the probability of it receiving initial stress from the driving of the bottom wedges, but assuming the bracing to be uninjured otherwise, it is thought the structure would have a factor of safety of about $1\frac{1}{2}$. Considering, however, the possibility of serious injury to the bracing by the depositing of the filling and riprap, the speaker advised Mr. Rollins to assume no responsibility for the safety of this structure,

The Contractor's Design. — The design for the shut-off dam proposed by the Holbrook, Cabot & Rollins Corporation is shown in Fig. 3. In making this design it was the aim of the contractor to provide a structure for the stability of which he was willing to assume full responsibility. This design differs from that proposed by the commission in the use of inclined piles to resist lateral pressure (thus placing less reliance upon the cross bracing); in using larger piles, which were to be not less than 12 in. in diameter at elevation 100 and $11\frac{1}{2}$ in. in diameter at elevation 94; in keeping all bracing above low water; in providing stronger bracing connections and making the bracing simpler in design and less likely to be injured by the depositing of filling and riprap; in the use of sheeting instead of stop-planks to hold the water; and in being a structure in which the filling may be readily deposited on both sides of the sheeting after the dam is closed.

The strength of the contractor's design was investigated under the same conditions as were assumed for the commission's design, the worst being with water in the basin at elevation 108 and in the harbor at elevation 100, the plane of rupture of the piles being taken at elevation 94, as before. Piles were to be Norway pine, of sizes above specified, and wales, sheeting and braces were to be yellow pine. The inclined piles were to be fitted to the vertical piles, which were to be notched to receive them, and at each connection the two piles were to be held together by two $1\frac{1}{4}$ in. bolts. The inclined piles were to be driven at a 1:3 slope.

In calculating the strength of the commission's and con tractor's designs, the factors of safety for timber were based on the values for ultimate strength recommended by the American Association of Railway Superintendents of Bridges and Buildings, at their 1905 convention, viz.:

Ultimate Strength of Timber.

(Pounds per square inch.)

	Compression.			Extreme Fiber Stress in Bending.
	End Bearing.	Cols. under 15 Diameters.	Across Grain.	
Norway pine............	6 000	4 000	800	4 000
Long leaf yellow pine....	8 000	.....	1 400	7 000

In both investigations, bolts are assumed to have an ultimate strength in bending of at least 48 000 lb. per square inch.

The inclined piles are assumed to be good for a direct axial compression load of 9 tons, with a factor of safety of 4, a figure which experience has shown to be a conservative one for the bearing power of piles in this locality. This load, by the *Engineering News* formula, would correspond to a penetration of 4 in. at the last blow for a 3 000-lb. hammer and a 10-ft. fall. The notched and bolted connection of the inclined and vertical piles is considered ample to apply this direct compressive stress to the inclined pile.

The method of determining the horizontal or lateral resistance of an inclined pile subjected to compression (using a factor of safety of 4) is illustrated in Fig. 8, in which is shown one of the inner inclined piles with its top cut off at elevation 105. At the assumed plane of rupture the pile has a diameter under the bark of at least 11½ in. and an area of not less than 104 sq. in., and the assumed load of 9 tons causes a direct compression at this point of 173 lb. per square inch. But the pile can safely withstand a maximum fiber stress in bending of 4 000 ÷ 4 = 1 000 lb. per square inch; it can, therefore, sustain a bending stress, in addition to the direct compression, of 1 000 — 173 = 827 lb. per square inch, a stress which would be caused by a horizontal force of approximately 900 lb. acting at the top of the pile. The axial load of 9 tons has a horizontal component of 5 700 lb. The sum of the two horizontal forces, 6 600 lb., represents the total lateral resistance of this inclined pile subjected to combined

compressive and bending stresses, with a factor of safety of 4. In a similar way, the lateral resistance of the outer inclined pile

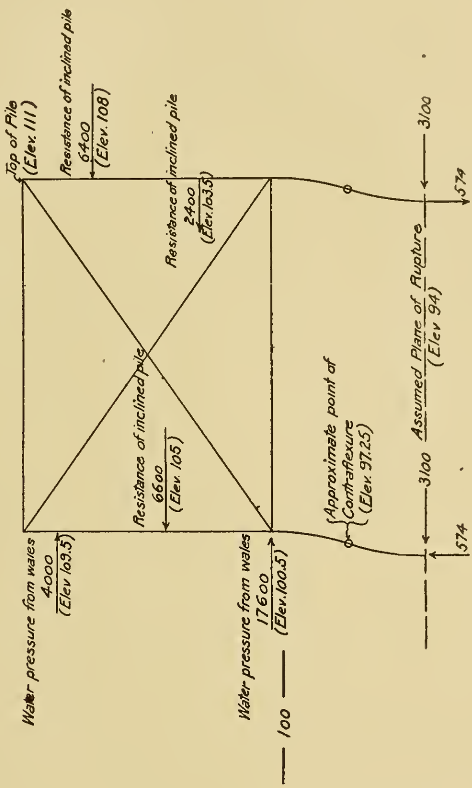


FIG. 9.

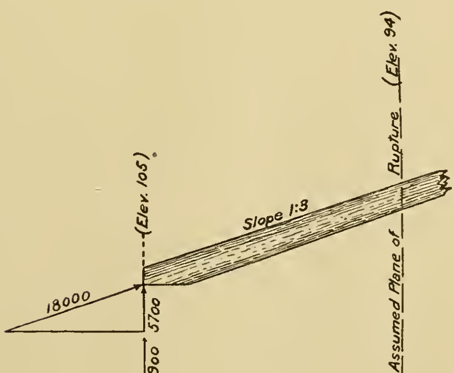


FIG. 8.

which is cut off at a higher level (elevation 108) is found to be approximately 6 400 lb. when subjected to combined bending and compressive stresses.

Reference to the contractor's design, Fig. 3, shows that there are in each bent two inner inclined piles sloping in opposite directions. A lateral force acting on the structure so as to put one of these piles into compression will at the same time subject the other to tension. The only tension or pull which the latter can receive, however, must be that applied to it by the bolts at its connections, the bolts being subjected to combined bending and shearing stresses. Doubtless the bolts in the cross bracing would come into action before the structure failed, but in computing the lateral resistance of this pile the only stresses considered were those applied to it by the two $1\frac{1}{4}$-in. bolts connecting it to the vertical pile. These bolts, acting in tension, as well as in shearing and bending, can subject the pile to bending as well as to direct tension or pull, although the pull on the pile will be found to be very small. Calculations show the lateral resistance of one of the inner inclined piles subjected to combined tensile and bending stresses to be approximately 2 400 lb. with a factor of safety of 4. Using the same factor of safety, the lateral resistance of the outer inclined pile, cut off at a higher level, is found to be approximately 2 100 lb. when that pile is subjected to tension as well as to bending.

The lateral resistance of the inclined piles having been determined, an analysis will next be made of the strength of the contractor's design. Refering to Fig. 3 it will be seen that the 6-in. yellow pine sheeting is in two lengths, the lower length being driven between guides consisting of the 8-in. by 12-in. wales which are bolted directly to the vertical piles and other temporary wale timbers on the opposite side of the sheeting. The lower sheeting is shown cut off at elevation 97. The upper sheeting, the driving of which was to stop the tidal flow, is offset 5 in. by placing 5-in. by 12-in. wales between it and the 8-in. by 12-in. wales, the offset being made to permit the upper sheeting to lap by the lower. Under the 8 ft. head of water assumed, the bending stress in the upper sheeting is approximately 400 lb. per square inch; but although it has a large excess of strength it did not seem best to reduce the thickness of the sheeting below 6 inches. The lower wales are placed at elevation 100.5, practically at mean low water, and the upper wales at elevation 109.5; like the sheeting, the wales have considerable excess of strength, their factor of safety under the 8 ft. head of water being more than 8.

In determining the strength of a pile bent, the vertical piles and cross bracing are considered as a framework similar to the end posts and portal bracing of a through bridge, the posts being

fixed at elevation 94, the assumed plane of rupture. This framework is subjected to horizontal forces due to water pressure applied through the wales, which forces are resisted, in part, by the horizontal resistance of the inclined piles, the several forces acting on the framework being shown in Fig. 8. Under this loading the framework would tend to deflect laterally in the manner indicated in the figure, the piles remaining substantially vertical at elevation 94 and elevation 100.5, between which points each pile would have a point of contraflexure at approximately mid-height (elevation 97.25). Under this condition of loading the maximum bending stress in each vertical pile is found to be about 800 lb. per square inch, this stress occurring at the assumed plane of rupture, elevation 94. The cross bracing is figured in the same manner as the portal bracing of a bridge. To secure a slightly better proportioned structure, the speaker recommended the substitution of $1\frac{1}{4}$-in. bolts for the 1-in. bolts in the lower horizontal cross brace, and if this plan had been adopted he understands the contractor would have made this change, although the 1-in. bolts would doubtless have developed ample strength.

It should be noted that the inclined piles will cause vertical forces to act on the vertical piles, which vertical forces are not shown in Fig. 9. Neglecting the weight of the structure, each vertical pile would be subjected to an uplift of between 7 and 8 tons; these uplifts would be considerably reduced, however, by the weight of the structure itself; they are far from sufficient to pull the pile, and their effect is to cause small tensile stresses which, combined with the bending stresses above noted, will cause resultant stresses in the vertical piles less than 1 000 lb. per square inch.

As a result of his investigation of the contractor's design, the speaker is of the opinion that this structure would have had a factor of safety of about 4 with the basin water level at elevation 108 and the water on the harbor side at elevation 100, the worst condition prescribed by the commission. According to the requirements of the specifications, this structure was designed for use during a period of neap tides and with the expectation that the water level in the basin would not fall below elevation 104 or rise much higher than elevation 108. The upper sheeting would have been driven by a number of pile drivers working simultaneously, and the driving of this sheeting (or the placing of the stop-planks in the comission's design) would have taken an appreciable time as against the time of one minute, or there-

abouts, required for the closing of the gates in the design later adopted. This structure would have cost less than that proposed by the commission and the speaker believes the contractor's design would have done the work well, although it probably would not have proven quite as satisfactory as the more expensive structure finally built.

Final Design. — Our respected president, Mr. Francis, to whom the question of the shut-off dam was referred by agreement between the Charles River Basin Commission and the contractor, proposed a design which the speaker considers a most excellent solution of this somewhat unusual problem; and this design, with some minor modification, was built and used with entire success. Certain good features of the commission's and contractor's designs were adopted by Mr. Francis, and others were proposed by him, chief among the latter being the suggestion of the sliding gates by means of which the tidal flow of the entire basin was checked almost instantly. The sliding gate idea is the most ingenious feature of the whole undertaking and Mr. Francis is to be congratulated upon its conception. The structure finally built was considerably stronger than that proposed by the contractor; its strength was easily sufficient to have withstood a head of water equal to the maximum range of spring tides, and thus would have allowed the shutting-off of the river to have been made at any time during the tidal month and with water in the basin at any level desired.

An investigation of the several designs for the shut-off dam emphasizes the fact that, if a pile structure is to be built to resist lateral pressure, it should not be made simply of vertical piles and bolted cross bracing, but that, for lateral stability, reliance should be placed chiefly upon inclined or batter piles.

President George B. Francis. — In the fall of 1906 I was consulted by Mr. Miller, chief engineer, regarding the plans made for this dam by those in charge of plans for the whole scheme, prior to the construction organization, some question having been raised by the contractors as to the feasibility of constructing this dam according to the original plans, which required considerable diver work, and also regarding its strength, compared with other plans of a more simple character to be constructed practically without divers.

After due consideration, I made a plan which appealed to me as better than any other which had been schemed, the main difference being the introduction of brace piles to the plan of simple character and an arrangement for attaching sway bracing

in the usual manner, above low water, rather than the wedge arrangement of sway bracing below low water on the original plan

It also seemed to me, as a secondary matter, that the original plan, which called for the placing of stop logs one by one, would take too long and might be attended with difficulties, so I arranged that the stop logs might be assembled as gates and these gates be suspended in gallows frames for a quick lowering, when the time came, by a very small force of men, compared with the individual placing of the stop logs.

Further consultation with Mr. Miller resulted in adding one more vertical pile in each bent on each side of the dam, and the dam was finally constructed in this manner, with the results as known.

The principal question regarding strength in any of the schemes was the shearing value of the piling at the point where they entered the earth, and it was practically impossible to make a satisfactory mathematical determination on this question, due to widely varying assumptions as to stiffness of earth, sizes of piles, etc. It was a question of judgment, largely, rather than one of figures without judgment.

The success of the undertaking, namely, the closing of a vertical area 672 ft. long and 16 ft. high in 7 seconds of time and its sufficiency for holding against the water pressure encountered proves that the subject had been well considered and carefully executed, with credit to all concerned.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1910, for publication in a subsequent number of the JOURNAL.]

RELATIVE EFFICIENCY OF THE DAY-LABOR AND CONTRACT SYSTEMS OF DOING MUNICIPAL WORK.

By Harrison P. Eddy, Member Boston Society of Civil Engineers.

[Presented before the Sanitary Section, Boston Society of Civil Engineers, February 3, 1909.]

The day-labor system of doing municipal work has been in use for many years both in this country and abroad.

Many of the duties of the municipality must necessarily be executed by day labor. It can hardly be imagined, for example, that the public schools would be turned over to a contractor to maintain and conduct; that police departments would be delegated to the contractors bidding lowest for patrolling the streets; that fire departments would be manned by crews furnished by the lowest bidders, — although it is true that insurance patrols are maintained in some of our American cities in whole or in part by insurance companies, and are said to be doing very creditable work. Neither is it easy to believe that serious consideration would be given to the operation by contract of the various penal and pauper institutions, the hospitals and the boards of health.

Street cleaning and the removal of snow, ashes, garbage and refuse of all kinds occupy, perhaps, a middle ground. There have been some instances where such work has been done by contract, although the great majority of cities have done it by day labor.

Inspection of work under construction is often performed by the municipality, but the inspection of materials purchased at a distance from the municipality is many times done by contract; thus to-day we find competent and reputable individuals or firms making a specialty of the inspection of cast-iron pipe, structural steel, cement and a multiplicity of other materials, who are given employment under contracts with the corporations and municipalities purchasing these supplies.

When we approach the question of municipal construction in the ordinary sense — the building of sewers and water works, the laying of street pavements and the building of schoolhouses — we are considering a field which has been occupied to a large extent by contractors, although in some places such work has

been done by the day-labor system. It is this class of municipal problems which I wish to discuss more particularly to-night, although confining what I have to say entirely to what are ordinarily known as the street, sewer and water departments.

In order to ascertain the general practice throughout the country, a postal card inquiry was sent to all cities in Massachusetts, and to all cities in the country exceeding 30 000 in population, as shown by the Census Bureau in 1905. The results of

TABLE 1.

RELATIVE PREVALENCE OF CONTRACT AND DAY-LABOR SEWER CONSTRUCTION IN AMERICAN CITIES OF POPULATIONS EXCEEDING 30 000. (Not including Boston.)

Population.	Number of Cities of Specified Size (1905 Census Estimate).	Number of Cities Enumerated.	Cities doing Work Wholly by Contract.	Cities doing Work Wholly by Day Labor.	Per Cent. of Cities doing Work by Contract.
30 000– 50 000	67	31	20	11	65
50 000–100 000	47	22	15	7	68
100 000–150 000	14	8	5	3	63
150 000–200 000	6	2	2	..	100
Over 200 000	20	10	10	..	100
Totals	154	73	52	21	71
Outside of New England	126	51	48	3	94
New England, excepting Massachusetts	10	6	4	2	67
Massachusetts	18	18	1	17	6

RELATIVE PREVALENCE OF CONTRACT AND DAY-LABOR WATER-PIPE LAYING IN AMERICAN CITIES OF POPULATIONS EXCEEDING 30 000. (Not including Boston.)

Population.	Number of Cities of Specified Size (1905).	Number of Cities Enumerated.	Cities doing Work Wholly by Contract.	Cities doing Work Wholly by Day Labor.	Per Cent. of Cities doing Work by Contract.
30 000– 50 000	67	26	9	17	34.6
50 000–100 000	47	15	5	10	33.3
100 000–150 000	14	6	1	5	16.7
150 000–200 000	6	2	—	2	....
Over 200 000	20	9	4	5	44.4
Totals	154	58	19	39	33.0
Outside of New England	126	40	19	21	48.0
New England, excepting Massachusetts	10	3	..	3	....
Massachusetts	18	15	..	15	....

that inquiry appear in Table 1. The questions were so worded as to apply only to ordinary extensions, and it is probable that in some cases work upon new systems may have been done by contract, while ordinary extensions were made by day labor.

From the foregoing table it appears that postals were sent to 154 cities, and that 73 replies were received relating to sewerage and 58 relating to the laying of water pipe. In the department of water-works extensions, one third of the cities furnishing information were doing the work by contract. Outside of New England, 48 per cent. were doing this work by contract, showing that the day-labor system is more generally adopted in New England than throughout the country as a whole. In New England, outside of Massachusetts, none of the cities heard from (there were only three) are doing work of this kind by contract, and none in Massachusetts.

Passing to sewer construction, it appears that out of 154 cities to which postals were sent, 73 replied, and 71 per cent. of those, or 52, were found to be doing work wholly by contract. Outside of New England, 51 cities replied, of which 48 were doing their sewer work by contract and 3 by day labor. In other words, 94 per cent. of the cities outside of New England were performing this class of work by contract. In New England, outside of Massachusetts, 6 out of 10 cities replied, and 4 of that number did the work by contract and 2 by day labor, while in Massachusetts, out of 18 cities, 17 do the work by day labor, showing what a great hold the day-labor system has in Massachusetts.

It cannot be maintained for a moment that the contract system of executing municipal work is free from abuse; in fact, it is probably subject to just as great abuse as the day-labor system.

There are several kinds of contracts which are certainly not favorable for municipal use. Among these is the system known as the "Cost plus a Percentage," and another is the system known as "Cost plus a Fixed Sum." The latter, perhaps, has some advantages, theoretical at least, over the "Cost plus a Percentage" system. The contracts which have been termed locally "gift contracts," and which are awarded without competition, should be condemned, and it is unnecessary to state, perhaps, that in this discussion contracts which are obtained by collusion are not included. Whatever comparisons are herein made are on the basis of contracts ordinarily known as the "unit price" or "lump sum" contracts. The "unit price" form

should be adopted wherever possible, but in many cases, undoubtedly, these two forms must be used jointly, and occasionally it may be wise to use the " lump sum " type alone. All contracts should be awarded upon a basis of full and free competition.

Advantages and Disadvantages of Day-Labor System.

There are alleged advantages and disadvantages in doing municipal work under the day-labor system, some of which are worthy of consideration.

Employment of Local Labor. — One advantage frequently claimed is that the day-labor system provides for the employment of local labor. This is a popular argument and one which usually secures support from aspirants for political honors. Everything else being equal, it certainly appears to be desirable that local labor should be given the preference. There are, however, under ordinary conditions, certain objections to this principle, among them the fact that local labor is often inefficient. This is found to be particularly true in case of small towns and cities, where there is not a suitable and adequate supply of common labor for undertakings of this class, especially if the work is unusual in character or amount. The employment of local labor generally results in the intrusion of politics into municipal departments, and that is, perhaps, the most serious objection which can be advanced to the arguments in favor of the adoption of the day-labor system, as it is directly or indirectly the source of most of the inefficiency. Furthermore, with local labor there is a very strong demand for all-the-year-round employment, and finally, the increase in the number of employees, which is so noticeable in many municipalities at or about the time of the municipal elections, is most unfortunate.

Saving Contractors' Profits. — Another argument used by those favoring the day-labor system is that the city can thereby save the profit made by the contractor. In other words, if the contractor makes legitimately a profit of 10, 15 or 20 per cent. of the cost of the work to the city, that amount would be saved to the community by employing the day-labor system. The answer to this argument in most cases appears to be that the increased cost of the work due to inefficiency more than offsets this apparent saving. In many places the wages paid to municipal employees are enough higher than the wages which would be paid by contractors to offset the contractor's profit.

Scamping and Incapacity of Contractor. — It may be argued that better work can be obtained when there is no incentive to

keep the cost down because of a direct financial return, as to a contractor. It cannot be denied that contractors have frequently made, and perhaps not infrequently succeeded in, the effort to curtail the cost of work at the expense of its quality. This is more likely to happen in the case of a contract taken at too low a figure to permit of first-class work and the payment of a reasonable profit thereon than in the case of a profitable contract. Losing contracts are universally considered as unfortunate alike to the contractor and to the party for whom the work is done. Competition is very desirable up to the point where it results in figures too low for first-class work. It is unfortunate, however, that when competition is keen there is a tendency on the part of the contractor to take chances and to slight the work.

Incapacity on the part of the contractor or his employees, or both, is more frequently a serious source of expense and annoyance in contract work than is the tendency to slight the work in the desire for greater profit. While it is possible under the usual terms of a contract to take work out of the hands of an incapable man in case of gross incapacity, this is always attended with additional expense. These conditions do not exist upon day-labor work, and to that extent the contract system is at a disadvantage.

On the other hand, both of these abuses can be met in large measure by a thorough system of inspection, if honestly administered, and under most city conditions equally good and sound work can be obtained under the contract system at lower cost than by a day labor.

Difficulty of Drawing Contracts for Complex Conditions. — The difficulty of drawing contracts to adequately cover the work done under complex and often unknown conditions existing in our larger cities is not infrequently advanced as a reason for doing work by day labor. Obviously there is some difficulty in drawing contracts that properly and safely cover complex city conditions, but it does not often exist in towns or in cities having a population of less than 50 000 or 75 000. It is, however, not infrequently experienced in a city like Boston, which is not only large and congested, but also an old city. This complication is, however, more apparent than real, and may be satisfactorily overcome in many cases by the use of unit prices and general clauses to cover unforeseen conditions, and the contractors who give the subject careful study can so make their bids as to reasonably cover such conditions.

There is no better illustration of the practicability of doing

this class of work by contract than that offered by the work of the Metropolitan Sewerage and Water Board (Massachusetts) and the Boston Transit Commission.

Substantially all of the Metropolitan Water and Sewerage Board work has been done *by contract*, regardless of the difficulties encountered, although an occasional section of work has been done by day labor.

The Boston Transit Commission has done *by contract* all of its complex work through the congested section of the city, — underpinning buildings, rebuilding old sewers and building its structures under many unknown and unforeseen difficulties.

While, therefore, there may be an occasional piece of work which undoubtedly could be advantageously done by a suitable and efficient day-labor force, there is not sufficient weight in this argument alone to warrant the maintenance of a permanent day-labor force.

Flexibility, Ease of Modifying Plans, etc. — The advantage of increased flexibility in construction under the day-labor system may be urged with some force. Conditions sometimes develop which make it desirable or perhaps necessary to materially modify or radically change the plans upon which a contract has been based. Such changes, after the letting of a contract, are always unfortunate and usually result in a loss to the party for whom the work is being done, the contractor being in the more advantageous position in the negotiations for the price to be paid for the work under the revised plan. If, on the other hand, the work is done by day labor, changes of any kind may be made at any time, often without unduly increasing the cost of the work, and sometimes even materially reducing it. It may well be claimed, however, that the difficulties attending the altering of contract plans lead to more careful and mature study of the problem before the preparation of the plans and hence in an ultimate saving in the cost of the work. These statements, of course, apply to changes not provided for in the contracts, and of such a nature as to require new prices and agreements, or otherwise to involve the city in litigation.

Saving in Cost of Inspection. — It may be argued that the saving in the cost of inspection is a distinct advantage of the day-labor system. This claim is obviously dependent upon the assumption that inspectors are not employed upon work done by day labor, and this appears to conform to the general practice. In answer to this claim it may be stated that there is much to be said in favor of the employment of inspectors upon work done

by day labor. There is a tendency on the part of foremen who are employed continuously by municipalities to become careless and, on account of lack of incentive, to fail to do first-class work. If the official in charge of the department is exceedingly anxious to do the work at least expense, the foremen are very likely to slight certain portions which may be of vital importance to the construction in hand. Experience would seem to indicate that it is of advantage to employ inspectors upon this class of work. If inspectors are thus employed, and if they are reasonably competent, accurate cost accounts can be kept, which is a sufficient advantage to warrant their employment, in which case this argument fails to carry much weight.

Difficulty of Fixing Responsibility. — Several disadvantages of the day-labor system may be claimed with considerable force; one of these is the difficulty of centralizing responsibility. One of the earliest impressions that a person gains in investigating municipal government is that there is an almost universal effort on the part of city officials to avoid taking responsibility, and it is at times exceedingly difficult to place the direct responsibility for expensive or unsatisfactory work upon any individual.

While there is in many cases justification for the claims of city officials that existing conditions are due to causes beyond their control, it would seem that the tendency to conflict between departments would be somewhat less under the contract system, which requires that the various problems be worked out in considerable detail before actual construction begins, than under the day-labor system, where there is a tendency to undertake work without mature study and preparation, and often largely to furnish continuous employment for labor.

Juggling of Appropriations. — Day-labor departments are not infrequently open to criticism because maintenance expenses are charged to appropriations for construction, or *vice versa*. This unfortunate condition arises very largely because of the effort to furnish continuous work. When appropriations to one account are exhausted and new appropriations are not forthcoming, there is a strong tendency to turn the force on to work that must come under another appropriation. In this way it has many times happened that unnecessary work has been done or that necessary work has been charged to an account to which it did not properly belong. If work upon construction is charged to maintenance, it of course unduly raises the maintenance cost, and if maintenance work is done at the expense of construction accounts, the cost of maintenance is not accurately recorded by

the books. If both maintenance and construction accounts are paid from tax levy, this condition is not likely to be as serious as if one account — for example, maintenance — is furnished from the tax levy and the funds for another account, construction, are furnished by long-time loans. The charging of maintenance work to long-time loans must be admitted to be a pernicious system, and if doing work by day labor has a tendency to increase this evil, it certainly would be better to do the work by contract. Of course it cannot be maintained that the mere adoption of the contract system will insure the charging of the expense of construction to the construction account, but even if it is wrongly charged, contract prices are, as a rule, a matter of record, and it is not impossible at some subsequent time to ascertain the amount thus erroneously charged; while, on the other hand, if pay rolls and bills are wrongly charged, it is almost impossible to obtain at some future time the amounts of such charges.

Age of Laborers. — Perhaps one of the most frequent criticisms by the public of day-labor departments is that the men employed are too old for the work they are required to do, and consequently that the amount of work done per man per day is ridiculously small. This appears to be the universal opinion, and unfortunately in many cases there is much to substantiate it. An investigation of the Boston sewer department recently made furnishes considerable interesting information pertinent to this criticism. Of the employees of this department, the investigation

TABLE 2.

LABOR EMPLOYED IN BOSTON SEWER DEPARTMENT CLASSIFIED ACCORDING TO AGE.

Present Age.	No. of Men.	Per Cent. of Force.	No. of Men above Ages Designated.	Per Cent. of Force above Ages Designated.	Term of Service. Years. Avg.	Max.	Min.
Below 20	1	0.1	—	0	2	2	2
20–24	5	0.7	20 — 714	20 — 99.9	3.2	9	0
25–29	19	2.7	25 — 709	25 — 99.2	3.8	12	0
30–34	53	7.4	30 — 690	30 — 96.5	6.1	15	0
35–39	101	14.1	35 — 637	35 — 89.1	7.5	18	0
40–44	127	17.7	40 — 536	40 — 75.0	9.9	22	0
45–49	136	19.1	45 — 409	45 — 57.3	13.0	28	0
50–54	95	13.3	50 — 273	50 — 38.2	12.7	32	0
55–59	81	11.3	55 — 178	55 — 24.9	15.3	33	2
60–64	65	9.1	60 — 97	60 — 13.6	14.8	35	1
65–69	21	2.9	65 — 32	65 — 4.5	13.6	21	1
70–74	9	1.3	70 — 11	70 — 1.6	17.3	23	11
75–79	2	0.3	75 — 2	75 — 0.3	32.0	40	24

included 715 connected with the labor service, The ages of the various employees, as well as their terms of service, were obtained from the state civil service records and are classified in Tables 2 and 3.

TABLE 3.

Classification of Labor by Term of Service and Age, Boston Sewer Department.

Present Age.	Years of Service.									Total.
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	
19	1									1
20–24	3	2								5
25–29	10	8	1							19
30–34	19	25	8	1						53
35–39	28	28	38	7						101
40–44	26	26	41	30	4					127
45–49	8	20	52	43	9	4				136
50–54	7	21	26	31	7	2	1			95
55–59	2	11	18	34	11	2	3			81
60–64	4	6	20	28	3		2	2		65
65–69	2	2	6	5	6					21
70–74	0	0	2	4	3					9
75–79	0	0	0	0	1				1	2
Total	110	149	212	183	44	8	6	2	1	715

Considering these tables as of the date of their preparation (1907), we find that of the 65 men who were from sixty to sixty-four years of age, 4 had seen less than five years of service in the department; 6 had seen from five to nine years' service; 20, between ten and fourteen years; 28, between fifteen and nineteen years, and *only 7 had served the department twenty years or more.* Of the 21 men from sixty-five to sixty-nine years of age, 2 had worked less than five years, 2 others from five to nine years, 6 from ten to fifteen years, 5 from fifteen to twenty years, and *only 6 had been employed in the department twenty years or more.* Of the 9 men from seventy to seventy-four years old, 2 had labored from ten to fourteen years, 4 from fifteen to nineteen years, and *3 only for twenty years or more.*, There was one man over seventy-five years of age, and he had labored *forty years or more for the department.* Sixty-one (9 per cent.) of the 715 employees had worked twenty years or more. *There were 97 employees over sixty years of age, but only 18 of them (18.5 per cent.) had served the department for twenty years or more.*

Right here I want to say that I believe a man who has worked for the city for twenty years is entitled to consideration, but in very few cases does he need charity, as appears from the following

statement: Of the 61 who were over forty years of age and who had served twenty years, 5 were upon work not inspected by us, 9 were employed as watchmen, which work they could perfectly well do, and there was need of a moderate number of watchmen in that department; 4 were filling positions for which they were not suited, and 3 were filling absolutely useless positions, leaving 40 men out of 56 coming under our observation who were performing laborious work. That leads us to ask of the necessity for the establishment of a pension system for the labor force.

The trouble with the labor force, as we found it, was that the men were appointed after they had passed their years of usefulness in the service of other employers. This policy turned the department into a sort of charitable institution where aged and infirm men were employed when they should have been the charge of relatives or of the public, and not placed upon the city pay rolls at wages higher than first-class able-bodied laborers at similar work could command from other employers, at the same time setting a very slow pace which their fellow-workmen, young or old, were bound to follow.

Wages of Laborers. — The effect of politics upon day-labor departments is very apparent in the matter of wages. The wages for common labor in the city of Boston from 1878 to 1883 for a ten-hour day was $1.75. In 1883 this wage was raised to $2. In 1891 the day was cut to nine hours, and in 1897 the Saturday half-holiday was allowed, *with pay.* In 1900 the eight-hour day was granted, together with the continuance of the Saturday half-holiday, and in 1907, with the same hours, the rate of wages was increased to $2.25, so that between 1878 and 1907 the rate of wages had increase from $1.75 to $2.25 per day, or

TABLE 4.

WAGES OF LABORERS EMPLOYED BY THE CITY OF BOSTON.

Nominal Time Worked and Wages Paid.			
Period.	Hours per Week.	Nominal Rate of Wages.	
		Per Day.	Per Hour.
1878–1883	60	$1.75	$0.17½
1883–1891	60	2.00	.20
1891–1897	54	2.00	.22½
1897–1900	50	2.00	.24
1900–1907	44	2.00	.27¼
1907–date	44	2.25	.30¾*

* To his should be added enough to offset the time allowed for legal holidays, which would bring this rate up to 31½ cents per hour.

28 per cent., and the hours of work had been reduced 26⅔ per cent.

The hourly wage, making due allowance for the Saturday afternoons and the holidays, had changed from 17½ cents to 31½ cents, or an increase of 80 per cent. in the cost to the city for the work done, assuming equal efficiency, which is a very doubtful assumption.

TABLE 5.

LENGTH OF DAY AND RATE OF WAGES OF COMMON LABORERS EMPLOYED BY LOCAL CONTRACTORS (BOSTON), 1907 AND 1908.

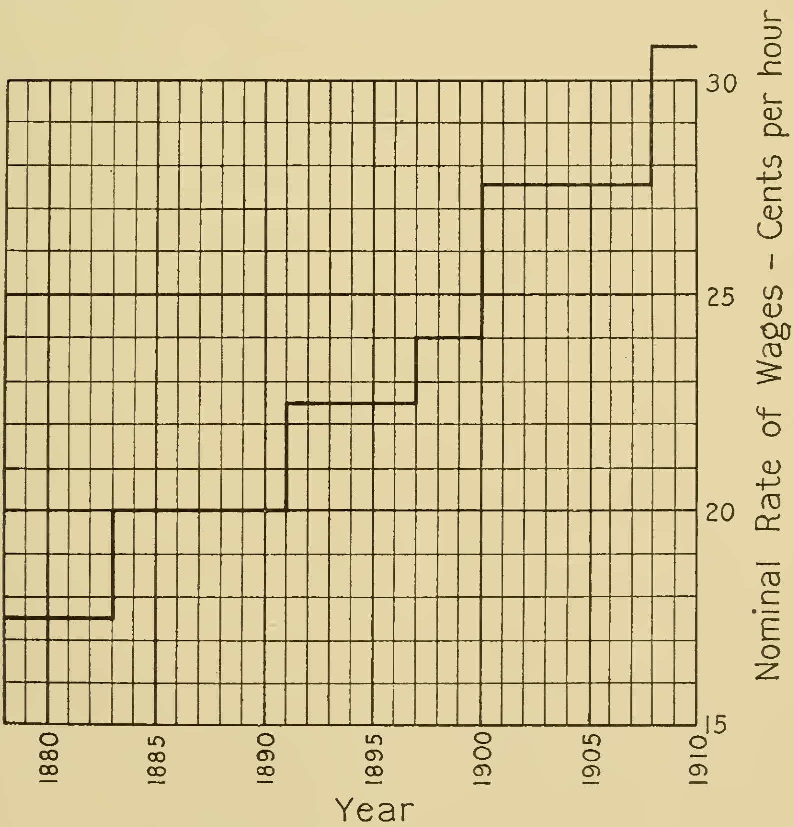
Contractor.	Number of Laborers. (Approximate.)	Length of Working Day. (Hours.)	Rate of Pay per Hour. (Cents.)
1	..	..	25
2	..	..	25
3	75	8	22
4	40–50	9–8*	17½–20†
5	50	10–9	20
6	..	..	20†
7	..	9	22 2/9†
8	12	9–8	22 2/9–25
9	10	9–8	25–30
10	..	8	20–25†
11	..	..	20–25
12	200	10‡	20
13	15–20	9–8	22 2/9†–30§
14	60–70	10–9	17½–19.4
15	100	9	19.4
16	..	10	15–16
17	..	10	16
18	..	..	$1.75–$2.00
19	40–45	8	22
20	20–150	9–8	20–28
21	75	9	19.4
22	..	8	25
23	6–50	10–8	25
24	91	8	20–25
25	..	8	30
26	25	..	30§
27	..	9	25
28	..	..	30‖
29	25	8	30¶
30	..	8	30
31	20	8	30¶
32	..	8	30¶
33	25–75	9	19.4
34	25	9	19.4
35	100	9–8	20–25
36	50–500	8	22½

* When 9 hr., from choice of men.
† Italian labor.
‡ Unless prohibited in contract.
§ Others than Italians.
‖ Union labor only.
¶ Same labor as employed for hod carriers.

Wages Paid by Contractors and Others. — An effort was made to ascertain the prevailing rate of wages paid by contractors in this vicinity for work similar to that performed for the city. Data were obtained from thirty-five different contractors and have been compiled in Table 5.

The minimum rate of wages paid in this vicinity appears to be 15 cents per hour, and the maximum did not exceed in any case 30 cents per hour. Comparatively few laborers are employed at rates of pay exceeding 25 cents per hour, while large numbers are paid as low as 20 cents.

NOMINAL HOURLY RATE OF WAGES OF LABORERS EMPLOYED BY THE CITY OF BOSTON FROM 1878 TO DATE



In general it may be stated that English-speaking laborers are paid more than others, and further, that the rate of 30 cents

per hour applies quite generally to building laborers, or to laborers who possess rather more than average skill.

In no case was it found that laborers were paid for legal holidays, and in only two instances were Saturday afternoons allowed. None of the contractors gave Saturday afternoons off with continued pay, and in no case were laborers paid in event of absence from work on account of injuries received.

The contractors with whom we conferred do not carry their employees through the winter unless they have work which must be done. In other words, they do not "find" work for their laborers during the winter season, as do the city departments, and consequently they do not give continuous employment.

Wages and Hours of Labor in Neighboring Cities. — Inquiries have been sent to sewer departments of all the cities in Massachusetts and several of the larger cities of the other New England states, and the statistics secured relating to the number of laborers employed, the length of day and the rate of pay, together with other data, are given in the following table.

Several of the cities included in this table perform their construction work by contract, so that the figures given in those cases apply only to the maintenance forces. From these data it appears that the prevailing length of day is eight hours, although in some cases a nine-hour day is required. Excluding Boston, the nominal rate of pay varies from 17 cents to 28.7 cents per hour, while the prevailing rate of pay may fairly be said to not exceed 25 cents per hour. In about one third of the cities the laborers are permitted to have half-holidays on Saturday, although in about one half of these cases the half-holidays are restricted to the summer months. In several of the cities where half-holidays are granted, the length of day is so arranged that the laborers work forty-eight hours during the week. In five cities granting Saturday half-holidays, laborers are paid in full for Saturdays during the summer months (varying from two to six months). Allowance for sick-leave in case of injuries received upon the work appears to be quite common.

Holidays and Sick-Leave. — The cost of holidays, half-holidays and sick-leave is an item the magnitude of which is not very generally appreciated. The Boston Water Department has very carefully compiled statistics relating to this source of expense, a portion of which has been reproduced in Table 7. During 1906 the distribution division expended upon pay rolls about $450 000, and the amount charged to holidays, half-holidays and sick-leave amounted to over $34 000, or 7.7 per cent.

TABLE 6.

Statistics concerning the Day-Labor Forces of the Sewer Departments of Various Cities.

City.	Number of Laborers.	Length of Day.	Rate of Pay, Nominal (per Hour).	Rate of Pay, Actual (per Hour), Cents.	Saturday Half-Holidays Allowed.	Pay for Saturday Half-Holidays.	Allowance for Sick Leave.
Lynn, Mass.	101	8	28 1/8	28 7/10	May–October	Yes	None*
Haverhill, Mass.	...	9	28 1/8	28 7/10	June–September	Yes	None‖
Fall River, Mass.	178	8½	28 1/8	28 1/8	Yes	....‡	None
Brockton, Mass.	70–100	8	28 1/8	28 1/8	No	....	None§
New Haven, Conn.¶	...	9	27 7/9	27 7/9	No	....	None*
Cambridge, Mass.	21	8	25	26 1/10	May–November	Yes	None
Springfield, Mass.	78–153	8	25	25 1/2	Work 7 hr.	Yes	None‖
Chicopee, Mass.	...	8	25	25	No	....	None*
Holyoke, Mass.	...	8	25	25	Yes	....	.....*
Lawrence, Mass.	114	8	25	25	Yes	....‡	Half pay
Lowell, Mass.	...	8	25	25	In summer	....‡	None
Marlboro, Mass.	...	8	25	25	No	....	None
Medford, Mass.	...	8	25	25	No	....	None
New Bedford, Mass.	86	8½	25	25	Yes	....‡	None*
Newport, R. I.	...	8	25	25	No	....	None
Waltham, Mass.	...	8	25	25	No	....	None‖
Newburyport, Mass.	5	8	25	25	No	....	None
Quincy, Mass.	...	8	23 1/8	23 1/8	No	....	None§
Worcester, Mass.	168	8	23 1/8	23 1/8	No	....	None
Hartford, Conn.¶	...	9	22 2/9	22 2/9	No	....	None
Waterbury, Conn.	14	9	22 2/9	22 2/9	No	....	None‖
Bangor, Me.	4	9	22 2/9	22 2/9	No	....	None
Fitchburg, Mass.	...	8	22	22	No	....	Full pay†
Albany, N. Y.¶	...	8	21 8/9	21 8/9	No	....	None
North Adams, Mass.	28	8	21 8/9	21 8/9	No	....	None‖
Newton, Mass.	75	8	21 8/9	21 8/9	No	....	None
Concord, N. H.	...	9	19 4/9	19 4/9	No	....	None*
Portland, Me.¶	...	9	19 4/9	19 4/9	No	....	None§
Hudson, N. Y.	...	8	18 3/4	18 3/4	No	....	Full pay
Providence, R. I.¶	84	9	17	17 2/10	July–August	Yes	None‖
New London, Conn.	40	9	16 2/3	16 2/3	No	....	None‖
Somerville, Mass.¶	8–15	8	......	......	In summer	....	None
Boston, Mass.	2 000	8	30 3/4	31 1/2	Yes	Yes	Full pay‖

* In case of injury, submitted to a committee.
† Full pay may be allowed not to exceed sixty days when approved by mayor.
‡ Work 48 hr. per week but time divided so that Saturday is a half-holiday.
‖ Full pay if injured on work.
§ Unless injured on work.
¶ Maintenance only; construction by contract.

of the total pay roll. The lowest percentage for any month was 5.3, and the highest a little over 10 per cent of the respective

TABLE 7.

AMOUNTS PAID FOR HOLIDAYS AND ABSENCE ("SICK LIST") OF MEN ON A PER DIEM RATING, BOSTON WATER DEPARTMENT, DISTRIBUTION DIVISION.

Date.	Total Pay Roll of Per Diem Men.	Amount Charged to Holiday and Sick List.	Per Cent. of Monthly Pay Roll.
1906.			
January 31	$35 191.68	$2 008.10	5.7
March 1	30 723.11	2 644.30	8.5
April 1	42 776.69	2 392.50	5.6
May 1	36 722.15	2 937.23	8.1
June 1	36 304.64	1 924.14	5.3
July 1	45 024.06	4 278.09	9.5
August 1	32 779.03	2 696.89	8.2
September 1	33 396.40	2 629.82	7.9
October 1	45 937.17	4 017.11	8.7
November 1	33 216.24	1 790.61	5.4
December 1	34 563.38	2 717.51	7.9
January 1, 1907	43 585.52	4 617.39	10.06
Year 1906	$450 220.07	$34 653.69	7.7
1907.			
January 31	$34 149.10	$2 412.46	7.1
March 1	34 125.93	1 991.45	5.8
April 1	43 061.28	4 344.48	10.01
May 1	34 005.68	3 150.70	9.3
June 1	33 976.41	1 815.40	5.4
July 1	42 695.08	4 181.27	9.8
August 1	35 952.67	2 853.42	7.9
September 1	44 399.06	4 357.44	9.8
8 months	$302 365.21	$25 106.62	8.3
Totals	$752 585.28	$59 760.31	7.95

NOTE. — Holidays: All city holidays and one-half day Saturday.
Sick List: From injuries on work, or absence on account of death in immediate family; in the latter case three days being granted.

pay rolls. During the first eight months of 1907 the money paid for holidays and sick-leave amounted to 8.3 per cent. of the total cost of labor. During this entire period of twenty months the pay rolls amounted to $752 000, and nearly $60 000, or 7.95 per cent. of the amount of the pay rolls, was expended for holidays and sick-leave.

Excessive Cost of Day-Labor Work in Boston. — Several matters were investigated by the late Boston Finance Commission which show quite clearly the excessive cost of doing work

by the day-labor system as it was found to be conducted at that time. Among these may be cited a test run of a stone crusher, the cleaning of catch basins, the maintenance of city teams, the manufacture of gate valves, the trenching in connection with laying small water pipe and the laying of sewers.

At the request of several citizens, the mayor of Boston authorized the continuation of work at the Chestnut Hill stone crusher, a municipal plant which had been shut down, for a period of three months during the summer of 1908, and requested us to send an assistant there to keep an accurate record of what was done, but not in any way to supervise or direct the forces. The work consisted of stripping and quarrying the stone, hauling it to the crusher and breaking it.

The test lasted three months, a period of time sufficiently long to demonstrate with accuracy the cost of producing broken stone at the Chestnut Hill crusher by day labor under the conditions of the test. The force consisted of men apparently as skillful and competent as could be selected from the employees of the street department, and certainly gave evidence of being reasonably skillful and competent. So far as could be observed, the foreman in charge was given an absolutely free hand to organize his force as he deemed best, and to adopt such methods of handling the work as he might desire. With slight and unimportant exceptions, tools and supplies were promptly furnished so that there is no reason to think that the output could have been increased by the improvement of conditions depending upon the coöperation of the superior officers of the department. The net result of this test appears to be that broken stone was produced at a cost of $1.07½ per ton. These figures make no allowance for the cost of the clerical service at the office or for the cost of administration, which items are estimated at 5 cents per ton, and no allowance is made for the cost to the city of the quarry.

A Member. — Any allowance for depreciation?

Mr. Eddy. — Yes, sir, and also for the rental of tools.

This experiment was carried on under the very best of conditions. The quarry and crusher were the most favorable of any which the city has worked in the past, and in 1895 produced broken stone more cheaply than any other of the city crushers. It is only fair to add that during the second and third periods of the test, the time being divided into three periods, there was a marked increase in the efficiency of the force employed. A fair estimate of the cost of the output of broken stone during these latter periods was 95 cents to $1 per ton, no allowance being

made for administration or for owning or maintaining the quarry.

For comparison we have found an instance where a large crushing plant of one of the broken stone companies was started with certain machinery that was rented to a contractor who crushed stone for a period of four or five months. The physical conditions were fairly comparable with those at the Chestnut Hill plant. The crusher was smaller, and the output was smaller than that of the Chestnut Hill crusher, and rental was paid for the machinery. The cost to the contractor of this work was 45 cents per ton, not including interest or depreciation. Including those two items, the cost was 50 cents per ton. It therefore seems fair to conclude that the work which cost the city practically $1.12 per ton, including administration expense, would have cost a competent contractor about 50 cents a ton. It should be borne in mind that this does not include any profit to the contractor.

Another illustration of the cost of day-labor work was found in the cleaning of catch basins in Boston. During the fiscal year 1906, as shown in Table 8, the records indicate that 7 768 catch

TABLE 8.

Cleaning Catch Basins. Comparison of Work performed by Day Labor and Contract from February 1, 1906, to January 31, 1907.

	No.	Per Cent. of Total Basins Cleaned.	Cost.		Per Cent. of Total Exp. for Cl. Basins.	Cost per Yard.
			Average.	Total.		
Basins cleaned by day labor	7 768	88	$6.39	$49 637*	92	$2.47
Basins cleaned by contract	1 068	12	4.15	4 429	8	1.46
Total	8 836	100	.....	$54 066	100	....

* Includes only charges for teams, labor and sub-foreman.

basins were cleaned by day labor at an average cost of $6.39 per basin, or $2.47 per cubic yard of material removed. In the same period, 1 068 basins were cleaned by contract at a cost of $4.15 per basin, or $1.46 per cubic yard. These contracts included, to be sure, some basins which did not exist on the ground and probably also some basins which had a lesser amount of material in them than was shown by the records at City Hall. There do not appear, however, to have been many of those

cases, and those which were found may have been due to clerical errors and were not sufficient to materially change the foregoing figures.

A large part of the excess cost of the work of cleaning catch basins was due to the method of operation; that is, the small number of hours of *actual work*. It was customary for each teamster, and two laborers to assist him, to report for work at the stable at 8 o'clock in the morning. It usually took some little time to harness, and it generally required a longer time to get on to the work. In cleaning a basin, so much of the refuse as was necessary to fill the cart was removed, and then the cart was hauled to the dump, one laborer going along with it, the other remaining beside the basin or waiting in the vicinity for the cart to return. In many cases it was found that teams made but one trip to the dump in the course of a half day, and at most four trips in the day or two in each half day. This was partly because of the length of haul, the time consumed in harnessing in the morning and in unharnessing at night, in driving between the stables and the basins to be cleaned in the morning and at night, and in returning (regardless of the distance) to the stable at noon for lunch. This gross waste of time could easily be remedied if it were not for the restrictions of the law, which stipulate that a department shall not request or require a man to work over eight hours per day or forty-eight hours per week, and even under the existing law good management would greatly reduce the waste.

In connection with the study of catch-basin work, a brief investigation was made of the cost of maintaining the city teams. The teams employed upon catch-basin work were charged to that account at the rate of $3 per day in 1906 and until July 1, 1907, after which time the price was raised to $3.50. Investigation showed, however, that only 37 per cent. in 1906 and 38 per cent. in 1907 of the actual cost of maintaining the teams was charged for their use, and that the actual cost, exclusive of the driver, was as follows:

1906, $2.73 per horse per day.
1907, $2.94 per horse per day.

It is interesting to note in this connection that the customary price about the city for stabling was at that time $1 per day per horse. Reduced to a comparable basis, a horse could be boarded at a stable for $1 per day, while it cost the city $2.25 or $2.40 to board it in the municipal stables during 1906 and 1907 respectively. The amount which should have been charged

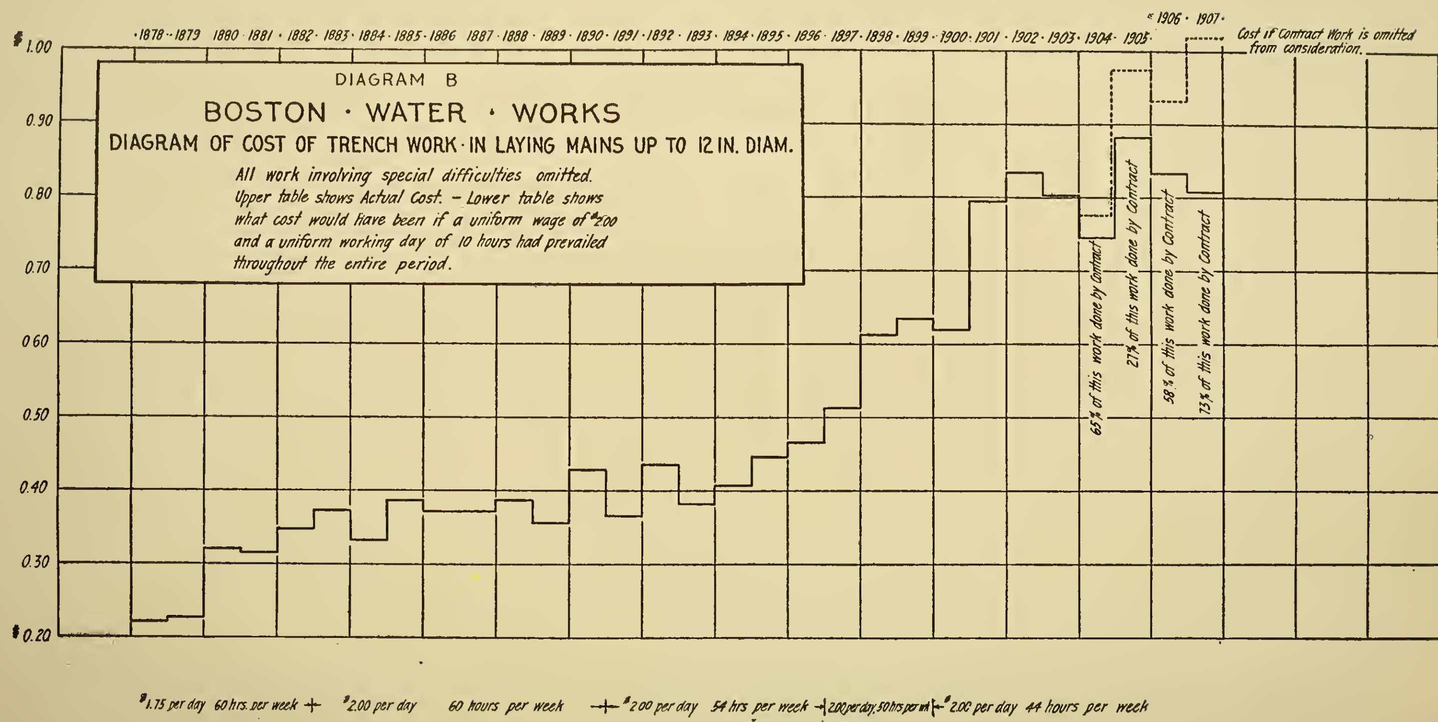
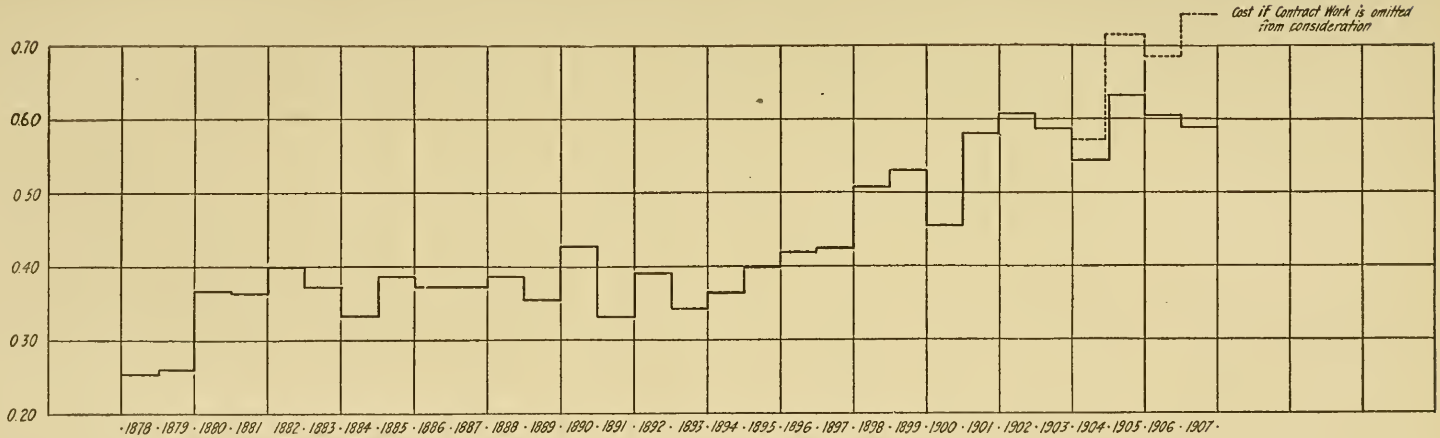


DIAGRAM B
BOSTON · WATER · WORKS
DIAGRAM OF COST OF TRENCH WORK · IN LAYING MAINS UP TO 12 IN. DIAM.
All work involving special difficulties omitted.
Upper table shows Actual Cost. – Lower table shows what cost would have been if a uniform wage of $2.00 and a uniform working day of 10 hours had prevailed throughout the entire period.
1878 · 1879 · 1880 · 1881 · 1882 · 1883 · 1884 · 1885 · 1886 · 1887 · 1888 · 1889 · 1890 · 1891 · 1892 · 1893 · 1894 · 1895 · 1896 · 1897 · 1898 · 1899 · 1900 · 1901 · 1902 · 1903 · 1904 · 1905 · 1906 · 1907
Cost if Contract Work is omitted from consideration.
65% of this work done by Contract
27% of this work done by Contract
58% of this work done by Contract
73% of this work done by Contract
$1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
$0.20
$1.75 per day 60 hrs. per week
$2.00 per day 60 hours per week
$2.00 per day 54 hrs per week
2.00 per day, 50 hrs per wk
$2.00 per day 44 hours per week


Cost if Contract Work is omitted from consideration
0.70
0.60
0.50
0.40
0.30
0.20
1878
1879
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1904
1905
1906
1907

during these years for the use of city teams appears to be approximately \$4.75 to \$5 per horse per day, including the driver's wages at \$2 per day most of the time, and \$2.25 per day during a portion of 1907. The excessive cost of maintenance above earnings amounted to \$1.75 per horse day, or 37 per cent. of the total cost to the city. If the city had charged the actual cost, the amount charged would have been increased by about 50 per cent.

For many years the Boston Water Department has maintained a shop for repairs and the manufacture of a portion of the gate valves, hydrants and smaller fittings required for construction purposes. The business of the shop amounted in 1907 to \$44 000. Table 9 shows the per cent. excess cost of manufacture of certain valves over the estimated cost if they had been purchased by contract.

TABLE 9.

EXCESS OF ACTUAL COST OF VALVES MADE IN BOSTON WATER DEPARTMENT SHOPS OVER ESTIMATED COST OF SAME VALVES IF MADE BY CONTRACT.

	Per Cent.
3-inch valves	36
4-inch valves	60
6-inch valves	53½
8-inch valves	32½
10-inch valves	47
12-inch valves	24½
16-inch valves	10
18-inch valves	12
24-inch valves	6

Under stress of investigation, and simply by the automatic stimulus of it, the cost of labor upon these gates was reduced about 35 per cent.

The city engineer of Boston has for many years kept a careful record of the cost of trench work connected with the laying of certain classes of water pipe. The results of this tabulation are shown by Diagram B. The upper line, beginning in 1878, shows the cost, per foot, of trench work for pipe 12 in. in diameter. In this compilation the engineers have carefully excluded all work done under unusual conditions, so that the figures are as nearly as possible comparable from year to year. The lower line indicates the same costs reduced to a uniform basis of wages and hours of labor. It will be noticed that during the first two years the cost per foot was little over 20 cents and during 1905 it reached about 88 cents. The cost, after reducing to a uniform basis of ten hours per day and \$2 wages, was, of

course, increased during the periods when the employees were receiving $1.75 per day, and decreased during the latter years, when the hours of labor and wages were less than sixty hours per week and more than $2 per day respectively, but does show with accuracy the relative efficiency of the labor from year to year.

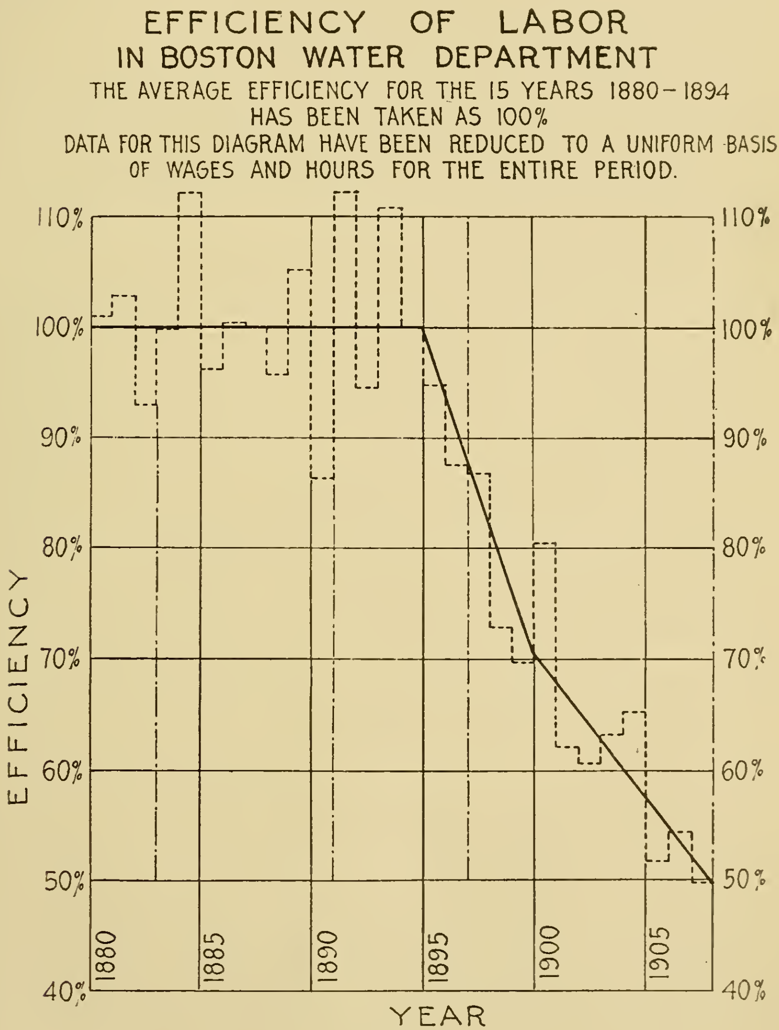

DIAGRAM C.

These data have been used in producing an efficiency curve, Diagram C, by averaging the cost of fifteen years (1880–94) and assuming that that average represents 100 per cent. effi-

ciency. Stating the premises in another way, the number of feet of pipe laid for $1 during those fifteen years represents an efficiency of 100 per cent. The variation from year to year is shown by the dotted line, and the average for fifteen years (100 per cent.) as well as the curve showing the general tendency from 1895 to 1907 by the heavy line. Beginning in 1895, it will be noticed that the line of efficiency fell gradually until it reached 50 per cent. in 1907.

From all the information available it appears that this study of cost and efficiency is based upon very full and reliable data, and that comparisons from year to year can be fairly made, although, of course, a better and safer result may be obtained by averaging several years and making comparison on that basis. In whatever manner the comparisons are made, it is apparent that the efficiency of the day-labor force has dropped about 50 per cent. in the last twelve years; in other words, in 1907 the average employee did only one half as much work in a given length of time as he did in 1895. In this connection it should be remembered that there are many causes for this decline in efficiency, some of which are entirely independent of the personal effort of the laborers and for which they should not be held in any way responsible. It is also true that this decline is not necessarily an inherent result of the operation of the day-labor system, and that this system has been in use in other cities for many years where no decline of such proportions is apparent. It is also interesting to note that the cost of work, Diagram B, was reduced by including with the work done by day labor also that done by contract during 1904–1907, in spite of the questionable methods of awarding the contracts.

Comparative Costs of Day-Labor and Contract Sewer Work in Various Cities. — The figures thus far given are almost wholly confined to the work of the city of Boston. However, many examinations and investigations have been made to determine, so far as possible, the comparative cost of building sewers by day labor and by contract, both in the city of Boston and in other cities throughout the state of Massachusetts.

To make this investigation less difficult and reduce the element of uncertainty as much as possible, the inquiry was confined to small pipe sewers, from 8 in. to 12 in. in diameter. Since most sewers of this class built in Boston have been constructed under contracts (largely "gift" or non-competitive contracts), the number built by day labor available for comparison was smaller than was desired. As the difficulty in select-

ing work done under comparable conditions was fully realized, and as such selection could only be made by engineers familiar with the conditions, an assistant was sent from place to place to

TABLE 10.

AVERAGE TOTAL COST PER FOOT OF COMPARABLE 12-IN. SEWERS LAID 10 FT. DEEP IN VARIOUS CITIES.

"A." Built by Day Labor.

City or Town.	Prevailing Diameter of Sewer. (Inches.)	Actual Total Cost per Foot.	Total Cost of Equivalent 12 In. Sewer without Allowance for Difference in Wages.	Subdivision of Cost into		
				Labor and Teaming Only.	Materials and Sundries.	Engineering.
Brockton	8	$1.73	$1.96	$1.20	$0.68	$0.08
Cambridge	8	2.35	2.58	1.70	0.81	0.07
Everett	8	2.09	2.32	1.55	0.68	0.09
Fitchburg	12	1.80	1.80*	0.95	0.77	0.08*
Haverhill	10	1.68	1.80*	0.90	0.82	0.08*
Lawrence	10	2.38	2.50*	1.80	0.62	0.08*
Lowell	10	2.30	3.42	2.35	0.98	0.09
Medford	8	1.80	2.03	1.05	0.92	0.06
New Bedford	10	1.88	2.00	1.30	0.67	0.03
Newton	8	1.65	1.88	1.05	0.73	0.10
Quincy	8	1.54	1.77	1.00	0.68	0.09
Worcester	12	2.00	2.00†	1.20	0.70	0.10
Average			$2.17	$1.34	$0.75	$0.08
Boston	12	$5.20‡	$5.20	$3.50§	$1.55	$0.15

* Engineering estimated $0.08 per foot.

† Exclusive of office and shop charges as in other cities.

‡ Not including proportion of undivided construction cost which amounts to about 5 per cent. of total construction cost.

§ Owing to the fact that this figure is based upon a comparatively small number of examples it should be used with caution.

"B." Built by Contract.

City or Town.	Prevailing Diameter of Sewer. (Inches.)	Actual Total Cost per Foot.	Total Cost of Equivalent 12 In. Sewer without Allowance for Difference in Wages.	Labor and Teaming Only.	Materials and Sundries.	Engineering.
Brookline	8	$1.73	$1.95	$0.80	$0.90	$0.25*
Portland	10	1.50	1.62	0.65	0.81	0.16*
Providence	12	1.68	1.68	0.65	0.83	0.20*
Somerville	8	1.75	2.05	0.90	0.91	0.24*
Average			$1.82	$0.75	$0.86	$0.21
Boston	12	$2.35	$2.35	$1.05†	$0.90	$0.40

* Engineering and inspection.

† Advertised contracts only.

NOTE. — That *no correction has been applied on account of differences in wages.*

NOTE. — That the *day-labor* cost shown in column 4 includes labor on manholes, whereas, the *contract labor* does not include this, but does include loss on sheeting, which substantially offsets it.

interview the local engineers, who always very kindly, and at times at considerable inconvenience to themselves, carefully considered the conditions surrounding a large number of pieces of work and advised which should be selected for use in this comparison. The number of sewers selected in each city was small, but included all which could be classed as being built under conditions enabling fair comparison. While it is realized that this study may be criticised as being based upon fragmentary and possibly insufficient data, it is presented as comprising the best data which could be obtained after a long and earnest effort to get at the truth. Unfortunately in no city except Boston was this class of work found to be done both by day labor and by contract, so that comparisons between the two methods in the same city were impossible, with the single exception noted.

From Table 10 it appears that the total cost per foot when reduced to uniform basis as to size and depth, namely, 12 in.

TABLE 11.

Cost of Labor, Teaming and Engineering upon Small Sewers built by Day Labor.

(Labor Costs reduced to Uniform Basis of $0.315 per Hour as paid in Boston. Data reduced to uniform basis of 12-in. pipe laid 10 ft. deep.)

City or Town.	Cost of Labor per Ft. inc. Teaming, excl. Office and Shop Charges.	Nominal Wage per Day of Eight Hours.	Actual Net Rate of Wage per Hour for Common Labor.	Cost per Ft. of Labor reduced to Comparable Basis. (Rate, $0.315 per Hour.)	Cost of Teaming per Foot.	Cost of Engineering per Foot.
Brockton.......	$1.20	$2.25	$0.281	$1.34	$0.03*	$0.08
Cambridge.....	1.70	2.00	0.267	2.01	0.06	0.07
Everett........	1.55	2.00	0.261	1.87	....	0.09
Fitchburg	0.95	1.75	0.220	1.36	....	....
Haverhill.......	0.90	2.00	0.250	1.13	....	....
Lawrence	1.80	2.00	0.250	2.27	....	....
Lowell.........	2.35	2.00	0.250	2.96	....	0.09
Medford........	1.05	2.00	0.250	1.32	....	0.06
New Bedford...	1.30	2.00	0.250	1.64	0.04	0.03
Newton........	1.05	1.75	0.219	1.51	0.06	0.10
Quincy.........	1.00	1.75	0.219	1.44	....	0.09
Worcester......	1.20	1.85	0.231	1.63	0.11	0.10
Average ...			$0.246	$1.79	$0.06	$0.08
Boston.........	$3.50†	$2.25	$0.315	$3.50†	$0.50	$0.15‡

* Contract teaming only. Department has one horse and wagon.

† Not including proportion of undivided construction expenses which amount to about 5 per cent. of total construction cost. Furthermore, owing to the fact that this figure is based upon a comparatively small number of groups, it should be used with caution.

‡ Estimate.

diameter and 10 ft. deep, averaged 2.17 in the twelve cities, not including Boston, where the day-labor system is in force; while in the four cities, Boston excluded, employing the contract system, the cost was $1.82 per foot. From columns 5, 6 and 7 it is evident that this difference is in the item of labor and teams, which amounted to $1.34 in the direct labor cities, as against $0.75 in those doing their work by contract, the items of materials and engineering being greater in the latter class than in the former.

In Tables 11 and 12 the labor costs of day-labor and contract work have been reduced to a uniform rate of wages with the hope of arriving at a basis which would allow of a fair comparison of the efficiency of labor employed under the two systems.

By putting the labor cost upon a uniform basis of wages, $0.31½ per hour, the actual rate paid in Boston, the average cost of labor alone in all cities not including Boston is increased to $1.79 per foot.

TABLE 12.

COST OF LABOR, TEAMING AND ENGINEERING UPON SMALL SEWERS BUILT BY CONTRACT.

(Labor Costs reduced to Uniform Basis of $0.315 per hour, as paid in Boston. Data reduced to a uniform basis of 12-in. pipe laid 10 ft. deep).

City or Town.	Cost per Foot for Labor and Teaming.*	Corresponding Rate of Wages per Hour.	Cost of Labor † reduced to a Comparable Basis. Rate of Wage, $0.315 per Hour.	Cost of Engineering and Inspection.
Brookline	$0.80	$0.22	$1.15	$0.25
Portland	.65	.20	1.02	.16
Providence	.65	.17	1.20	.20
Somerville	.90	.22	1.29	.24
Average	$0.75	$0.20	$1.17	$0.21
Boston‡	$1.05	$0.25	$1.32	$0.40

* Exclusive of labor in manholes, but including loss on sheeting. It is estimated that these two items substantially balance each other so that the figures are directly comparable with the *day-labor* figures of Table 11.

† It should be noted that contractors in Boston usually pay but $0.25 per hour for labor unless required to pay higher wages by the city.

‡ Advertised contracts only.

By comparing the figures in column 5, Table 11, with those of column 4, Table 12, it is seen that the cost of labor where work is done by contract was far below the cost of that done under the day-labor system.

TABLE 13.

BOSTON SEWER DEPARTMENT. COMPARISON OF COSTS OF CERTAIN COMPARABLE PIPE SEWERS LAID IN BOSTON BY DAY LABOR AND BY CONTRACT.

Location.	How Done.	Date.	Length. (Feet.)	Size.	Average Cut. (Feet.)	No. M. H.	Rock, Cubic Yard.	Cost per Linear Foot.	Cost per Foot on Equal Terms.	Ratio of Day Labor to Contract. Costs per Cent.
Allston Place between Woodstock Avenue and Corey Road, Brighton...	Day	Jan. 27 to March 2, 1905	$304.03	12	10.5	2	(?)	$5.59	$5.59	2.4
Corey Road from Allston Place, 400 ft. southwest, Brighton...............	Contract	Aug. 23 to Sept. 17, 1907	400.00	10	12.3	2	4.81	2.42	2.34	
Willow Street between Dunbar and Weld streets, West Roxbury.........	Day	Aug. 18 to Nov. 9, 1905	1 126.57	12	11.6	5	(150)	7.74	7.74	3.2
Maple Street between Adington Road and Weld Street.................	Contract	Jan. 10 to May 25, 1906	1 100.00	12	10.7	6	218	2.25	2.45	
Dunboy Street between Hardwick and Bigelow streets................	Day	Sept. 16 to Oct. 1, 1904	175.65	12	7.0	1	No	5.13	5.13	3.7
Hardwick Street, Bigelow to Dunboy Street.......	Contract	May 2–18, 1904	756.4	12	7.2	4	18.89	1.41	1.38	
Revere Street, between Charles and 136 ft. west.	Day	July 28 to Aug. 16, 1906	132.3	12	14.4	2	.....	13.98	13.98	2.1
Tennyson Street between Church and Pleasant streets................	Contract	Oct. 26 to Nov. 10, 1906	221.07	12	10.6	...	1.66	5.05	6.48	

Charles Street between Revere Street and 230 ft. northerly..............	Day	June 11 to 13, 1904	230.6	12	10.5	...	.....	5.96	5.96	Rush job 2.0
Hale Street between Green St. and Hale St. extension	Contract	June 8 to July 3, 1903	269.3	12	11.7	2	.....	3.35	2.98	
Charter Street between Phipps Street and Marshall Place............	Day	June 30 to July 20, 1905	191.57	15	10.6	...	.....	7.79	7.79	1.48
Hanover Street between North Bennet and Charter Street..............	Contract	Oct. 28 to Nov. 30, 1906	333.33	12 / 15 / 18	9.3	...	.....	4.68	5.26	
South Street, Kneeland to Beach Street...........	Day	Jan. 30 to May 2, 1903	318.1	18	16.6	...	.....	21.39	21.39	2.78
Fayette Street, Church St. to Ferdinand Street ...	Contract	Sept. 16 to Dec. 5, 1906	384.7	18	13.1	...	.....	6.29	7.68	
North Street, Blackstone Street to North Center Street.................	Day	Nov. 4 to Dec. 17, 1903	141.51	30 by 36 brick	12.6	...	....	45.44	45.44	2.74
Cooper Street between Washington Street, North, and Endicott Street................	Contract	Aug. 5 to Oct. 10, 1907	210.1	30 by 36 brick	12.6	...	....	16.54	16.54	

NOTE. — These pieces of work were picked out by the district engineers as substantially comparable.

Linear foot costs are based on total cost of labor, teaming, explosives and supplies, excluding engineering and administration, office and yard department, cost of materials, i. e., pipe, brick, cement, manhole covers and steps. In each comparison the linear foot costs are reduced to terms of like diameter of sewers and like average depth of trench.

Putting the matter in a different way, it appears that if the work which was done by day labor had been done by contract, the average cost of labor (uniform basis) would have been reduced from $1.79 to $1.17 per foot, a reduction of nearly 35 per cent.

Comparing the work done by both methods in the city of Boston, it appears that had the work done by direct labor been done by advertised contract, the reduction in cost of labor would have amounted to over 62 per cent.

Comparative Costs of Sewers Built by Day Labor and by Contract in Boston. — In Table 13 have been compiled the costs of pairs of sewers so selected as to be as nearly as comparable as possible. In each pair one sewer was built by day labor and one by contract. After reducing the costs to equal terms as to size and depth it appears that in the case most favorable to day labor, the cost by direct labor was double that by contract, and this ratio in one case was increased to 3.7 times the cost by contract.

It would not seem unreasonable to expect that some relation may exist between the rate of wages paid and the efficiency of labor, or, in other words, that enough more work would be done per hour under the higher wages so that at least as many feet of sewer would be laid for $1 as in cases where lower rates of wages prevailed. The following tabulation (made up from Table 11) shows the number of feet of sewer laid for $1 when the wages are reduced to a uniform basis of calculation. The percentage of efficiency is calculated on the assumption that the Brockton labor was 100 per cent. efficient.

	Rate of Wages Actually Paid.		Number of Feet of Sewer laid for $1 figured on Uniform Basis.	Per Cent. Efficiency assuming 100 Per Cent. Efficiency in the One Case when Wages = $0.281.
	Per Day.	Per Hour.		
Brockton........	$2.25	$0.281	0.746	100
Seven cities	2.00	.254	.529	70.9
Worcester.......	1.85	.231	.613	82.1
Three cities	1.75	.219	.694	93.0
Boston..........	2.25	.315	.286	38.3

While it may not be fair to draw the conclusion from these figures that labor is less efficient because of higher wages, it does seem to follow that higher compensation does not assure greater efficiency. The greatest efficiency was apparently obtained in the case of the city of Brockton where the nominal

wage is $2.25 per day, although in Boston, where the same nominal wage is paid and holidays granted in sufficient number to increase the rates per hour over 12 per cent., the lowest efficiency was indicated. Averaging the results obtained in cities paying the same rate of wages, there appears to be a gradual decrease in efficiency as the rate of pay increases.

Reasons for Inefficiency of Day Labor. — The investigations which we have made into various lines of municipal work all lead to the conclusion that work done by day labor almost invariably costs the municipality more than that done by contract. There are several reasons for this; one, and perhaps the most important reason, is the intrusion of politics into the departments; another is the lack of direct financial responsibility and interest on the part of the city officials. The contractor is dependent upon the profits of his work to make a living, while the tenure of office of the city official is not ordinarily dependent upon the cost of the work done by his department. This difference in the interest of the contractor and official has an automatic and a very important bearing upon the efficiency of the management. Another cause of inefficiency in municipal departments is the lack of heads of departments who have been educated and trained for the particular kind of business which they have to do. With the exception of city engineers and city solicitors, it is rather the exception than the rule to find officials who have been fitted by education or experience for their duties. Executive departments require technical and special knowledge, and, in addition, administrative ability, often found to be lacking in the officials in charge.

One reason for inefficiency is the lack of knowledge of what work actually costs. Very few city officials know in terms easily carried in mind what their work really does cost. There is also a scarcity of data making possible a comparison of costs of similar work done in the same city and different cities.

The improper balancing of forces is a frequent cause of inefficiency. It often happens that a day-labor foreman is working one third or one half of the laborers he should have, while the cost of his time and that of timekeeper, watchmen, water boy and other fixed and overhead charges are as great as if he had a full force of men.

A very important matter is the failure of city councils to pass appropriations early enough in the year to make it possible for department heads to organize their forces and lay out their work so as to prosecute it economically. In some cases, especially

in the smaller cities, it is not possible for day-labor departments to provide the most economical machinery. In very few municipalities is there an effective and efficient organization. Many times the foremen are appointed in much the same way as heads of departments, without regard for proper training or qualifications. Day-labor forces are frequently overloaded with laborers and the numbers are not reduced when the quantity of work is diminished. Such a policy not only increases the cost at the time, but encourages an indolence or laziness on the part of employees which has an important effect upon the efficiency of the force when there is plenty of work to be done.

Remedies for the Inefficiency of the Day-Labor System. — The next important question is what can be done to remedy these conditions which have been found to be so prevalent where municipal work is done by day labor. The first suggestion, and, I believe, a most important one, is that the contract system should supersede the day-labor system upon all work which can be done by contract. This suggestion is not popular and is not likely to be adopted where politics and not good government is the chief aim. In placing the change to the contract system first, it is held that the greatest good, the most efficient system, is likely to be secured by contract. In this way municipalities will probably get the most for their expenditures.

It is not contended, however, that the contract system *per se* is a guarantee of good and efficient work. If politics are allowed to mix with municipal business, it will surely result in demoralization, and just as great abuses are possible under the contract as under the day-labor system.

But under the best conditions of to-day, and in the cities where the works departments are known to be well managed, the indications are strong that the work costs much more under the day-labor than under the contract system. From the foregoing data it seems fair to conclude that in general a saving in cost amounting to 30 per cent. could be effected by doing work by contract rather than by day labor under existing municipal conditions.

It is undoubtedly true that there are some advantages in the day-labor system, and in view of the general adoption of this system, especially in the eastern part of the country, it may be well to consider a few steps which can be taken to secure greater efficiency.

A fundamental necessity is the adoption and conscientious execution of an adequate system of accounting by which the

costs of doing various classes of work are accurately known. Such accounts should include the proper proportion of fixed and general charges, including salaries, office, shop and stable expenses, engineering and all other similar items, so that the total amount of money expended can be subdivided and charged to the several items of work done. There should be no pool into which such items are thrown, with the result, as has been found in some cities, that a large proportion, perhaps as high as 15 per cent. or 20 per cent. of the money expended, is not charged to work done. Shop and stable expenses should be wholly charged off to work accounts, and while it is usually fair and reasonable that there should be an office account to receive such items as are of a general nature, such, for example, as giving information to the public, such an account should amount to only a very small fraction of the entire expense account. Accounts should be subdivided into such items as can easily and fairly be compared from year to year and with similar accounts of other cities.

The expense of work should be so itemized that the unit costs, such as cost per cubic or square yard or linear foot, are available and in units easily carried in mind.

Probably the most effective way to secure efficient day-labor work, and at the same time to place the city in a position to know exactly how much more or less it costs to do work by this system than by contract, is to subject all work to open and free competition. To accomplish this the work should be so divided that each portion would be of suitable size for a profitable contract. Several pieces should be advertised at one time in local papers and in suitable trade journals of wide interstate circulation, thus giving local contractors every means of knowing about the opportunity of bidding and at the same time inviting propositions from outside the municipality. The advertisements should state clearly that the city will select a certain number of jobs which will be done by its own direct labor organization, and that while in general it will select those upon which its own estimates are below the tenders of contractors, yet it is under no obligation to so restrict its choice. Exceptions may very wisely be made in cases where the city's estimates are low upon one kind of work and where some work of another kind is very desirable to maintain a proper organization and make the greatest use of the plant owned by the city. For example, the city may have a well-organized skillful gang for rock work and a suitable plant for such work and yet its low estimates be all for work involving only earth excavation. It is conceivable that under such circum-

stances the city would be justified in selecting some of the rock work, even though its estimates were somewhat higher than the tenders. It must be remembered that if the day-labor organization is to be maintained in an efficient condition, it must be provided with a nearly uniform quantity of work of the kinds which it is organized and equipped to do.

The city should prepare estimates of the cost of doing by day labor every piece of work advertised, and in general should select for its own force those pieces upon which its estimates are lower than the corresponding tenders.

Such a plan must be so carried out as to command the respect of contractors and, therefore, it would seem to be wise to have the work done under the general direction and to the satisfaction of the same engineer in both cases. If the works department is organized under a superintendent independent of the city engineer, this can easily be arranged. If it is under the direction of the city engineer, its management should be delegated to one assistant, and the engineering and inspecting to another assistant, who also has charge of similar work done by contract. In any event, every effort should be made to secure the same quality of work in both cases, that all comparisons may be fair.

The annual report should include a table of bids received and estimates made, and the cost of each piece of work done by day labor and by contract. From such data it will be very easy to determine whether or not it is wise and economical to do work by day labor, and such comparisons will aid materially in securing efficiency from the day-labor force.

DISCUSSION.

Mr. Charles R. Gow. — From experience in the use of both classes of labor under discussion, I think I can safely say that inefficiency of labor is not peculiar to municipal work. We have it in contract work just as often as we have the same inefficient supervision and faulty system of control. And I suppose that the reason municipal work as a rule costs so much by the day-labor method is due to the fact that the system has grown up with municipal administration, which has made it peculiarly conducive to inefficiency. Mr. Eddy, I think, has covered the ground fairly well as to the cost. But as he spoke, some additional features occurred to me that might have some bearing on the matter.

In the first place, the rate of wages paid for foremen and superintendents in municipal and most government work is, as

a rule, I think, less than is paid by the large contracting concerns doing the same work on the same scale, and that would mean, of course, that a much less efficient class of foremen would be carried by the cities than by the contractors. We have found from experience that some foremen are cheap at $10 a day, while others who might be willing to work at from $2.50 to $3 a day, would be very expensive. As an illustration, I once worked as superintendent of a large contracting concern in New York. They had previously done railroad work, and they were engaged at the time on the construction of one of the large subway sections there, and brought on a lot of these foremen to handle that work. And the first criticism I made after looking over the work was that they did not have a sufficient number of competent and experienced foremen. I was told to hire any foremen I knew who were suitable for the work, but when I mentioned the fact that we should probably have to pay $150 a month for such foremen as I had in mind, the president of the company threw up his hands. After considerable argument he finally agreed to allow me to engage two such men as I wanted at that salary. The first of these men who happened to appear on the work was put in the place of a $3 man. And his first act was to discharge six men out of the gang, and in his first day's work the result was an increase in output of 25 per cent. And this increase in output, as I remember it, represented a value of something like $35 to the contractor. That would illustrate in a way what I mean when I say that the high-priced foreman is oftentimes cheap in the end.

The cities, of course, establish a fixed rate for their foremen as a rule. There is no promotion by merit, and there are seldom any questions asked as to the ability of the foreman, provided he comes with the proper credentials from the civil service or other department. Of course, the average laborer will do no more work than he is required to do, whether he is working for the city or for a contractor. And unless he has competent supervision the results cannot be expected from him. The political aspect of city labor was pretty clearly dealt with by Mr. Eddy. Of course, its demoralizing effect is unquestioned. It was in order to correct the evils of political control that the civil service system was inaugurated, and yet to my mind that is even a greater evil as regards labor inefficiency than political control. When, some years ago, I was acting as superintendent for the Boston Transit Commission, in charge of their contract labor, we had some six hundred men employed. That was on the

original subway, doing some special work where it was adjacent to buildings, or in localities where it was feared the contractors might lead the commission into difficulties. We were obliged under the law to procure all the labor from the civil service list. And the most difficult feature of the whole undertaking was to secure a gang of men that we could do anything with at all. The trouble seems to come in this way. The good men, the efficient men, are seldom out of work for any great length of time. The value of their services is well recognized by contractors, and as soon as they finish up one job they secure other work, if there is work being done. Consequently they don't take the trouble to register with the civil service commission and wait their turn before they are certified for employment. The majority of the men who do register with the civil service commission are men who can't find employment in any other way and simply look upon the city as a good asylum from which to obtain an easy living. The result, as we found it, was that if we wanted 25 men to start a piece of work, we would make requisition for 100, and out of that 100 probably 50 would appear with high standing collars and patent leather shoes, and some of them on crutches or otherwise disabled. And we would be expected to select from that crowd a gang of men to go down 25 or 30 ft. below the surface of the ground to brace trenches and excavate in wet and difficult ground. I can readily understand where the city departments may be seriously handicapped on that account and where a really conscientious official would have serious difficulty in obtaining a gang of men that would be suitable for his needs.

The next evil that suggests itself to me is the influence of labor unions. The labor vote, of course, is of such consequence that it can't be ignored by political office-holders if they expect to continue in office. And the result is that labor councils have been allowed wide latitude in dictating the details of labor administration. It is one of the avowed principles of the labor unions at the present time to so regulate the output of men as to make positions for the largest number of men possible. And they consider it perfectly legitimate to so cut down the output of one man as to make room for a second one doing the same work. Of course where this is allowed to prevail, as I believe it is largely in the city employ, it can't be expected that efficient service can be maintained.

Then there is the question of discharging men in the city employ. Now that they are under the protection of the civil service, it has become a matter of considerable difficulty for a

foreman to get rid of an inefficient man. And I can readily see where all these things combined can tend to raise the price, as Mr. Eddy has shown. The matter of employing citizen labor is very fine in sentiment, but it hardly makes for economy. The contractors found long ago that the available supply of English-speaking labor was practically exhausted, that is, the supply of competent labor. And they were obliged to turn to foreign labor, not so much as a matter of economy, as a matter of necessity. My own experience is that we pay practically the same rates of wages to the competent foreigners that we do to equally competent Irishmen or Americans. And while we would much prefer to have the English-speaking man to the foreigner, we find it impossible to obtain a sufficient number of competent men. And as a matter of fact, the Italian labor at the present time is becoming scarce. The better class of Italian laborers to-day can command and receive $2 a day, when business is good, for common labor. We pay some of them who are skilled a little beyond the average as high as $3 a day. We pay a minimum wage in our company of 17½ cents an hour, and an average for common labor of probably about $2.10, which is not a serious handicap to day labor as a matter of competition.

I am inclined to take issue with Mr. Eddy as to the possibility of day work being done better than contract work. My experience and observation lead me to a different conclusion. I have noticed that where day labor is in vogue, as a rule there is no inspection, and where there is any conscientious endeavor to do the work cheaply, it is carried to the same extreme that a contractor is apt to carry his work in doing it cheaply. I have in mind an instance I noticed a few years ago in one of the cities nearby where bids were asked for the construction of a covered waterway, a brook channel, I think it was. And for some reason all the bids were rejected and the work was done by day labor. In that case there was an inspector on the work who appeared to me to be a little more ambitious to hustle the work along and to do it cheaply than even the foreman himself. Most of his energies were given to pushing the work. On that particular piece of work there was a concrete arch, very flat, as I remember it, and not more than 12 in. in thickness. And at the time I noticed the work they were concreting this arch and imbedding in it field stone as thick as they could get them and still have them come within the limits of the sections. Now, so far as I know, no serious trouble has occurred from that type of construction, but I rather imagine that if a contractor suggested that to an inspector

or an engineer he would be told a few things. There are several other cases I have in mind where contracts have been called off and bids rejected and the work subsequently done by day labor, and the engineers or inspectors, having the contract price in mind as an upset price which they must not exceed, have stretched their consciences materially to keep within the limits under the disadvantageous conditions they were put to by the labor situation and expense.

As a general thing, in letting contracts, the disadvantages that Mr. Eddy referred to, and which I admit are considerable, could largely be overcome if the engineers would show a little more courage oftentimes in rejecting low bids and the bids of incompetent parties, and insist, as far as they are able to do so, on awarding the work to competent parties at what would be a fair and living price. We all of us make mistakes in our bids. We often overlook important items. You understand, of course, that the working engineer has had months, perhaps, to think over the problem and to think over the obstacles and the difficulties to be encountered, while the contractor is obliged to form his judgment in a few days, and oftentimes the best of contractors make serious mistakes in estimating the work, and consequently bid ridiculously low. Of course, there is a certain spirit among contractors as well as other business men that makes them feel like standing up and taking their medicine under such circumstances. And oftentimes they would appreciate a suggestion from the engineer that he would like to have them retire under the circumstances and allow him to award the contract to a higher bidder. It is not impossible to find out by a proper investigation just what the ability of the contractor is and whether the work in question is beyond the limit of his ability. It seems to me that it would be perfectly proper, and should almost be deemed necessary under the circumstances I have outlined, to advise the awarding of the bid to some other contractor. And if this were done in all cases I think that the difficulties that arise out of contract work in some cases could be largely overcome.

The question of day labor versus contract work will probably never be entirely settled. It is probably generally admitted that day work must cost more than contract work. But there is a question whether or not, in a certain measure, the public does not wish to accept the conditions as a concession to policy and sentiment, provided the difference is not excessive.

A Member. — I'd like to inquire of Mr. Eddy whether in

making his comparison any attention was given to the relative amount of rock excavation in other places as well as in Boston?

Mr. Eddy. — Yes, sir. Each city was visited by one of our assistants, and the officials in actual charge of the work were questioned, and in every case went over in great detail all of the work. Criticism of the figures I present lies, I believe, not so much in that, but in the comparatively few jobs we found it possible to reduce to a comparable basis. For instance, in most of those cities I think there were not over 8, 10 or 15 sewers, and that will illustrate the great difficulty of securing comparable information. If there was rock, that was allowed for or the job thrown out. If there was quicksand, it would have to be thrown out, and there were numerous cases of that kind. We had the greatest difficulty in getting a reasonable number of comparisons even in Boston, and we got those from the engineers who were on the work. About all I can say for it is that it was the best we could do. I do not think any of those figures should be taken too literally, but I do believe they show honestly and fairly the general tendency. The comparison may be unfortunate in some cases.

A Member. — I'd like to inquire about the dates of construction of the work used in comparison.

Mr. Eddy. — I think there was nothing back of 1905. It was mostly work of 1906 and 1907. Is that right, Mr. Butcher? Mr. Butcher knows more about the details than I do.

Mr. W. L. Butcher. — Yes. It is so long ago that I don't think I could go into any discussion of the details, but it is a fact that all the work represented was done since 1905.

Mr. Adams. — I'd like to discuss one detail that Mr. Eddy spoke of, and that is the great difficulty of making reasonable comparisons. It is something which seems to me to be of great importance. I had occasion a year or two ago to make comparisons of costs in various cities, and it was with the greatest difficulty that anything could be made out that would give a fair and satisfactory comparison of costs. The State Bureau of Statistics of Labor is now busy and has been for some years in publishing costs, that is, the expenditures of the various municipalities for the various departments — street, sewer and I think all of the other departments of the various cities. But they don't go into the matter of what the city gets in return for its expenditures. They have outlined a certain scheme which they believe is wise to follow in making up their statistics. That is not a scheme that perhaps any particular city follows. We know, for example,

how difficult it is to say in construction work, for instance, what was included in the report of a city because of the costs of sewers and streets. Another city will include different things. For example, Arlington, when it constructed its system of sewers some years age, included in the costs it reported practically all of the office force. It included the cost of making the preliminary plans; in fact, it included nearly everything except the salary of the superintendent. Most cities omit all of that. In most of the cities, I think, very meager reports are given. In Quincy, for example, and in Chelsea, no report is given that amounts to anything. They just give lump sums, and there is no possibility of making any comparisons from the reports that they have made. It seems to me that the very good work that your committee is doing, the committee for which Mr. Eddy reported before his address, might well be extended. It covers, it seems to me, everything except that one item of physical conditions. It will cover, when the cities make their reports satisfactorily, all the financial end of it, but not the physical end of what the municipality gets in return for its money. If I may refer to one or two cities in this vicinity, it seems to me that Somerville is giving almost ideal reports. I should like to call attention to the form of the report of the city of Somerville on its sewer construction. I have it here: Cost, location of sewer, the material excavated, the name of the contractor (they do nearly all their work by contract), the average cut, the size of the sewer and sub-drain, the amount of rock excavated, the price per cubic yard of rock, the number of manholes, the average cost of the manholes, the number of inlets and the unit price of these various items, and, in addition, other things, such as the cost of inspection; and some cities include also the cost of other engineering work besides inspection and the cost of materials when the city supplies them, and also the amount of the assessments that are levied. This system is followed more or less, mostly less, by the other cities. But they are not on a uniform basis, and it is almost impossible to make a satisfactory comparison. For example, Cambridge and Brookline give quite a good deal of information. The Brookline sewers, for instance, are given in a good deal the same form as those of Somerville, but the depth of the sewers is omitted. In some cities the sewers are twice as deep as they are in others, so it is impossible to compare fairly a sewer that is 6 ft. deep with another that is 30 ft. deep. And most of the cities, as I have said, omit reports altogether. It seems to me that these things primarily and other things are

needed to give a fair statement of what a sewer costs. There are great difficulties in the way I can see. One of the difficulties is that the total amount of expenses connected with such work does not all come in one year. There is the matter of land damages, which ought not to be included in the matter of cost, but ought to be included in what a sewer costs the city, and yet these damages do not come in until many years after the construction of the sewer. So one of the questions which ought to be considered by such a committee as we have, and which I believe ought to be considered by the Commonwealth, is that of compelling the cities of the Commonwealth to give their reports to the Bureau of Statistics of Labor all on the same basis, which would not be a difficult thing if the cities went at it with that end in view. But at the present time each city makes its report as it chooses. I know from conversations with Mr. Eddy about the difficulties of getting even financial statements that we now have a very limited number of cities that know what their sewers cost them.

Mr. Dorr. — Mr. Eddy, in discussing the comparison of day labor and contract labor, has spoken very fairly and ably of the demoralizing influence of politics on the day labor. But he has not touched on what would happen if the same things interfered with the contract system. When politics gets into the contract system and interferes with and demoralizes the inspecting force, then most of the advantages of the contract system will disappear. The costs will be increased by inefficient and venal inspectors, and not only that, but the quality of the work will be demoralized. The result will be that the work will not be economical and will also be bad.

Mr. Manley. — Mr. President, one thing in connection with the contract system is this: There are a lot of cities in this country doing a large amount of this sewer and water and similar work, and street construction work, but it is in detached sections, and each section is under a separate contract. There are the specifications and the advertising and the letting of the contract for each separate section of work, and then the contractor is constantly organizing and disbanding his force for these small jobs, and it always seems to me that there is an enormous waste in that. It seems to me that if these sections of work were advertised in a large enough lump, so that a better class of contractors would be attracted, it would be possible thereby to diminish the cost and to make a distinct saving. It has seemed to me for many years that something of that kind could be done with

proper supervision and management, and that, accepting the contract system as that to be followed, it would result in a material saving.

MR. EDDY. — That opens up a wide, interesting and important subject, and one with which I have had occasion to deal at very considerable length during the past year. There were, approximately, 250 sewer contracts let in the city of Boston within, I think, three years, all comparatively small contracts. And most of them I have referred to incidentally as "gift contracts." While that does not come strictly within the scope of Mr. Manley's question, it illustrates what can be done. Those 250 contracts were so arranged geographically that all could have been included in 50 groups, and in that way would have made contracts of reasonable size, say, of $10 000, $15 000 or $20 000. That would illustrate roughly the sizes of the contracts. But there is a practical difficulty in that. If you take the contracts let in the city of Boston in three years you will find that some of them were required on account of conditions which existed in 1908, but which did not exist in 1905. That is a real difficulty which you are sure to run into. I think the real solution of that problem falls back upon business management of your city. If you can secure a government which can handle these things according to business methods, many of these contracts can be grouped together, and even if they are not let under one contract, a good many of them can be let at one time, so that perhaps one contractor can get three or four contracts. I think the wise method, wherever possible, is to so group the contracts that you can have a piece of work large enough to warrant contractors in putting on a plant and effecting an organization sufficient to handle it economically. The whole question of improvement of contract method is rather beside the subject of this paper, but Mr. Dorr has spoken of one very important feature which ought to be touched upon in connection with a comparison of contract and day-labor work, and that is the effect of politics upon contracts, which is, perhaps, just as bad as it is upon day-labor work.

MR. ADAMS. — I think there is one way in which the efficiency of day labor may be increased and which has not been mentioned so far. It is one I had to use a number of times where the work could not be done by contract, and it is now being used quite extensively in the Reclamation Service in the state of Washington and perhaps in other parts of the West. The plan is to divide the day-labor force into two or three sections which shall

work on substantially similar work and be practically of equal size numerically. In that way there is a competition between these two or three sections, a sort of friendly rivalry, and it has always resulted when I have used it in increasing the output quite materially, perhaps as much as 25 per cent., and in some cases of which I know, even more than that.

MR. FELTON. — I might say that Brockton did all its work by contract labor, and when we started to do city labor, I was a very strong advocate of the contract system. But to-day I think I have possibly changed my mind a little. It is still an open question, and yet I think that in Brockton, under our conditions, it would be difficult for a contractor to do our work as cheaply as we are now doing it by day labor and pay the same wages. Mr. Eddy's chief points for the contract system, and the only points, are the incentive, which is of tremendous importance, and the fact that the city is forced to pay higher wages than the contractor under present conditions. Under our conditions, it would be impossible, probably, to let contracts without a clause stipulating that the contractor should pay $2.25 per day for a minimum wage. Our system there, as shown in those figures, seems to be very close to what we pay; that is, $1.20 a foot, I should think, is very close to what it would add up. We sometimes run our sewers, in fact, two years in succession, at $1.43 and $1.42 per foot, including all materials. It is true in all cases that everything is in there, that is, every dollar that is spent is in there. And paying the same rate of wages, I doubt whether a contractor would make much profit at that cost. Our conditions are practically ideal. We run the same organization entirely through the year, starting in the moment the frost is out of the ground and never stopping until the ground is frozen up again, when we close down entirely, and employ practically new men the next year, except the foremen, whom we maintain the year around. Our work is almost uniform in quantity, from 3½ to 5 miles every year. There are, perhaps, some indirect benefits in the day-labor system. Mr. Eddy has covered most of them. It is possible in the day-labor system to give employment to a large number of citizens. This may decrease disbursements in the poor department—probably does to a great extent. And the money that is paid out is circulated almost entirely within the city's limits; none of it is taken out of town. In relation to the day-labor system, it seems to me that the opportunities for graft are less, the temptations are less than would be the case in the contract system. There is no opportunity for collusion except-

ing in the purchase of materials, and as to the matter of good work, I am almost inclined to agree with Mr. Gow that the character of the work obtained under the contract system is even better than under the day-labor system. I don't think poor work, as a rule, is due to fraud or a desire for fraud, but is almost all due to carelessness or ignorance.

Speaking of public sewers, for instance, the proportion of the work that could be slighted is so small, and the risk is so great, that no contractor would do it for the amount involved, as a rule. It would be done carelessly rather than otherwise. Of course, as Mr. Eddy has said, it might be in a great many cases a good idea possibly to have an inspector on the ground. But so much of the time there is nothing to inspect in our case, where we have a good organization carried over from year to year, that we deem it good business to allow one of the laborers who has a little extra bit of skill to look after the laying of pipe, for instance, when the foreman is employed on some other part of the work. I cannot believe that those figures are comparable there where they show a cost of $1.13 in Haverhill and $2.96 in Lowell. I cannot conceive that conditions can be in any way comparable under those circumstances. It is a very risky matter to compare costs per foot on sewers. I wish that some gentleman from Lowell were here to account in some way for the $2.96. As to the engineering costs, they seem to run fairly close in most of the cities, and in all cases include the preliminary and final plans and assessment plans. Though if that is true where they run down to 3 cents per foot I should doubt.

Mr. Johnson. — The only satisfactory thing about the showing of the city of Boston seems to be in that last column there, engineering, 15 cents. That is the prize feather for engineers.

Mr. Branch. — When day work was proposed in Quincy I felt very shaky about it. I thought it was unwise, to say the least. Our construction work there extended over a period of about eight years, and from the start we thought it advisable to employ a certain amount of day labor. And in the first two or three years we got a force organized so that we were able to do any of the sewer work the city had to do. My own whole experience leads me to believe that with a proper organization, as good an organization as we can get in Quincy, we can do work as cheaply by day labor as by contract; that is, that work costs no more when done by day labor than when done by a contractor, if the contractor gets a reasonable profit. A careful study of the

cost to the contractor of work done under these unit prices per cubic yard, etc., showed that wasn't always paid to the contractor. And then the costs of certain sewers done by day labor seemed to be very large for certain grades of work. And I made a study of the force accounts of contractors on similar work. I found one street where there was no water, a perfectly dry street, where, of course, the contractor or the city either would have to anticipate no difficulty in construction, but the work actually cost the contractor for items which I knew, and I didn't pretend to know all the items of cost to the contractor, but the items I was sure of cost the contractor two and one-half times what he thought they would. I found over a period of some three years, looking at sewers where there was a water depth of from 10 to 20 ft. in trenches, a number of instances, in fact, in nearly every instance, that the force account showed the cost to the contractor was one and three-quarters to three times the price he received for the work. And I found that the work lost in the same proportion. There was work done by the city by day labor which was done at a considerably lower price than the lowest price made by any contractor. That was the easy work, the kind the contractor would make money on. And I also found that when either contractor or city gang got on a difficult proposition the work went slower. And I did not find that very many contractors' foremen handled the work very much better than the city's foremen did. For several years practically all of our work was done by day labor. The cost seemed to be so much larger than some of our contracts that the commissioners thought it would be possible to make a change and to go back to the contract system. And the last year that we did any considerable amount of work on construction we let half the work that year, perhaps, by contract. And I noticed that the unit prices were nearly double what they were five years before. Contractors had got wise and were not making such ridiculously low bids on work. It is not possible, of course, to compare two pieces of work. But it was perhaps as nearly possible under the conditions we had that year as it would be at any time. There was one piece of 20-in. sewer of which we took the middle section out for the day gang and the remainder we let by contract. And then other work was done, and at the close of the season I estimated what the cost would have been at the unit price paid to contractors, and not allowing that the contractors would have any bills for extras, which they usually do have, the labor items would have cost about 13 per cent. more if the work had been done by contract than it actually did cost as

done by day labor. Of course, I do not know what it would have cost if it had been done by contract, but using the unit price we paid that year to contractors, those were the results. So that as a result of all my observations, if a man can be let alone and have help to please him, and if he can have the organization in force long enough to get it to a reasonable degree of efficiency, I believe work can be done by day labor as cheaply as by contract, where the contractor makes a reasonable profit. I got myself into a bit of a hole by taking a little sewer contract after I had left the employ of the city and using as a basis of what a gang ought to do what had actually been done by the city gangs. I organized a gang with local labor in the town and I found that it cost me anywhere from 50 to 70 per cent. more for the same work than it cost the city of Quincy, and my only salvation was that some of the water-works gang got laid off and I was able to employ them, and so I finished up the work with town employees and in that way managed to pull out without a loss.

Mr. Gow. — One more point suggested itself to me that might cause discussion, and that is the fact that at the present time contractors, like every other class of men, are specializing more or less. And we have at the present time in this vicinity certain contractors particularly efficient at paving work, others at dirt moving, others subway work, others tunnel work, and so on. Where the work to be done in a city is of a varied nature, it isn't to be supposed that their own force of laborers, or their own foremen or superintendents will be equally proficient at all these different classes of labor. Whereas, if bids were asked, it would result in each job attracting the men who are specialists in that particular line of work. It would attract the specialists, and they would either be the low bidders, or would force somebody else to go below their figures, possibly at a loss to the contractor. Nevertheless, it would conduce to lower prices on the work. And that, I think, is one of the greatest advantages to be obtained by a municipality in letting its work by contract.

Now, in regard to the matter of costs. It is some years since I have done sewer work. We have rather drifted away from it largely to other classes of work. But some years ago I did quite a large amount of sewer work for Boston, and my recollection is now that in cases of average digging and average conditions in the sewer trench of the size and depth indicated on that chart, we found $1 a foot to be a very profitable price for doing the work; that is, $1 a foot bid. And my recollection is that the actual cost averaged from 60 to 65 cents a foot, which left a con-

siderable margin of profit. And unless there were special difficulties attached to the work, we were very glad to get $1 a foot for the work at that time.

MR. FELTON. — What wages did you pay?

MR. GOW. — We were paying $1.75 for 10 hr.

A MEMBER. — I don't wish to prolong the discussion. But one or two thoughts occurred to me, and one of them is that I don't think the comparison between the cost of work by contract and the cost of work by day labor is entirely fair because the conditions under which the city works are so different from those under which the contractor works. For instance, the city is required to go to the civil service for its employees, or, at least, the city of Boston is, and the contractor is not. The city is required, because it has to go to the civil service, to take American citizens, because no man can register with the civil service, as I understand it, who is not an American citizen. Further than that, the city work is limited to 8 hr. a day, and the contractors in their contracts agree not to require their men to work more than 8 hr. a day at the present time. I think the last legislature said they should not request them or require them. But of course it is very difficult to see that that law is not violated, because the mere fact of a man's working longer than 8 hr. does not prove that he has been requested or required to do so.

Now, in those comparisons that have been made, these three things do not show — these three conditions under which day labor must be more expensive, because it is a different class of labor and is working under different conditions. Further than that, it shows very clearly what becomes of the old and feeble, but we don't know what becomes of the old and feeble who have spent their lives working for the contractor. If they have become poor and unable to support themselves, they have to be supported just the same at the public expense. Now, that is an item, of course, which we can't figure. And if we are going to make certain conditions in the city under which labor shall be employed, I think we should require contractors to conform to them. If the city is compelled to employ, or does of itself employ, none but American citizens, it should require the contractors to employ none but American citizens. All of the conditions should be the same. Then I believe the cost would be very much the same.

MR. FELTON. — I know from the figures Mr. Gow gives that he regards 50 per cent. as a legitimate profit.

MR. FRENCH. — On the subject of the civil service regula-

tions. I understand that a measure is coming before the legislature by which contractors employed on public work shall not be allowed to permit men to work over 8 hr. a day. That is the next piece of legislation. Mr. Gow referred to one thing that struck me with considerable force, and that is the matter of accepting the bids of contractors when we know them to be absurdly low. That is one of the things we are running against constantly, and I have been a good deal in doubt as to the position we ought to take, for I have gathered from such contractors as I have talked with about it that they would feel very much worse to be refused the contract than to be allowed to go ahead and pocket the loss. So there you are. I don't think any responsible contractor would be willing for me to use my judgment as against his in a matter of that kind. I don't know how Mr. Gow would feel.

Mr. Felton. — I wish you gentlemen who are not afraid to speak out would give us some more talk about the civil-service men.

Mr. Manley. — There is one point that has got to be considered, and that is aside from politics, labor unions or anything else of that kind — the humanitarian aspect of the system. Formerly the merit of the foreman was to get as much work as possible out of his men. It used to be said that he took the full shovel every time. Now, while the work is scarce, the contractor can pick and choose his men, and he can say to those men, if they do not appear to be doing their work properly, "You can go," while the foreman has to go through strikes and troubles of various sorts and keep right with his men. Another point is about old-age provisions and all that, which Mr. Eddy referred to in his paper in so sympathetic a manner. All that has to be taken into consideration. The tendency of the time brings that into account. Men have got to be taken care of more than formerly. When times are good, contractors will pay almost any old price. But when the times are hard, and they succeed in getting contracts, then, as has been said, labor is more efficient.

President Johnson. — It seems to be a question whether the city suffers most from grafters or the reforms represented by the civil-service men.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1910, for publication in a subsequent number of the Journal.]

REFORESTATION OF THE MARGINAL LANDS OF THE WACHUSETT RESERVOIR OF THE METROPOLITAN WATER WORKS, BOSTON, MASS.

By E. R. B. Allardice, Member Boston Society of Civil Engineers.

[Read before the Society, April 21, 1909.]

That forestry, from a commercial standpoint, can be successfully carried on has been demonstrated for scores of years in the European countries of Switzerland, Germany and France. These countries have been, and are to-day, utilizing large portions, if not all, of their waste and timber lands in developing and extending their lumber resources, and have proven beyond a doubt that forestry can be put upon a dividend-paying basis. Even in our own country, where this industry has but recently assumed proportions worthy of note, it may be considered as a paying proposition.

If this be true where only one result, the financial, is to be obtained, is it not doubly so when carried on in connection with large water supplies where there are to be other and, perhaps, more far-reaching results accomplished?

In the early development of the plans for building on the south branch of the Nashua River, at Clinton, Mass., what is now known as the Wachusett Reservoir, in which to store water for the supply of Greater Boston, the Metropolitan Water Board, largely through the efforts of one of its members, Dr. Henry P. Walcott, appreciated the fact that, unless systematically and scientifically studied and developed, the marginal lands of this great inland lake, which aggregate 3 380 acres, and in places extend back for half a mile, would become waste and valueless, a detriment to the purity of the water supply and a menace to the life of the soil. A small part of this large tract was made up of arable and pasture land which could be used for farming and grazing purposes; but, on account of the fact that manurial matters would result from such utilization, all idea of allowing cultivation and pasturage was abandoned as being even more of an injury to the purity of the water supply than the non-use of the land would be. There remained but one alternative: to reforest in some way the whole or a part of this reservation.

To determine the kinds of trees to be used, methods of treatment and the various other questions of policy in this reforestation, the Board secured the services of Prof. J. G. Jack, of the Harvard Agricultural School, a recognized authority on sylviculture.

Professor Jack made a thorough detailed study of the existing condition of the various kinds or classes of land, and outlined a general scheme to be followed, whereby the most economical use could be made of the land and at the same time preserve and increase the purity of the water supply, protect the land against damaging floods, increase the duration of heavy yields and preserve the usefulness of the soil.

It will be seen at a glance from the foregoing that the benefits to be derived in establishing a complete forest cover over the marginal lands, besides being a good investment from the lumberman's standpoint, will prove of incalculable value to the water supply and will warrant the required expense.

In entering upon this work, the promoters did not have the advantage of others' experience. Although forestry, as forestry alone, had been practiced successfully for years, it remained for this project to make of it an important branch of the modern large water supply. Therefore, the first question to be decided was: How can this large area of land be reforested, to secure the most satisfactory results, without affecting, to the slightest degree, the paramount purpose of securing a pure water supply? Had the problem at hand been one of forestry pure and simple, it would not have contained so many perplexing conditions, for then those portions of the reservation especially adapted to commercial forestry would alone have been considered, and the balance, for the present at least, left to nature.

With the problem at hand, Professor Jack found an area made up of small parcels so varied in growth, soil and topography that hardly any two offered the same treatment. The arable lots, pastures and sparsely grown sprout lands offered a splendid opportunity for the practice of modern forestry. The more hardy sprout lands and timber forests could, by the expenditure of comparatively small amounts, be made paying property by cutting out the dead and undesirable trees, thereby giving more light, air and nourishment to the remaining hardy specimens, and assisting nature in the development of a valuable forest. The large areas grown to herbaceous plants, sedges and scrub oaks, of which a large percentage of the reservation was

composed, which, therefore, could not be neglected in the solving of the problem, offered an excellent opportunity for experimental features in sylviculture.

As the result of his investigation, Professor Jack recommended that the entire unforested portion of the reservation be planted with native white pines, making a self-perpetuating forest, which would ultimately provide a complete ground cover, requiring no artificial fertilizing or disturbing of the soil, and which would protect the waters of the basin from the direct contamination of manurial matters and soil washed from adjacent farms during heavy freshets or spring floods. The white pine was selected because of its almost universal adaptability to the various kinds of land and growth to be treated, its freedom from leaves, its rising value in the lumber market, and the ease, low cost and certainty of raising it to maturity.

The policy having been outlined and adopted, the real work of raising from seed the trees to be used in the field and the improvement and protection of the existing forest stands began, and it is of a description of this work that the principal part of this article consists.

An outline of the general policy adopted in the reforestation of the marginal lands of the Wachusett Reservoir, comprising as they did 1 090 acres of arable, pasture and light sprout land; 280 acres of thick sprouts and young, thin timber land; and 1 475 acres of heavy timber or forest land, was as follows: first, to establish two forest nurseries, one on each side of the reservoir, for the raising from seed of coniferous trees, mostly native white pines, to form the ultimate or final forest, and of deciduous trees to act as fillers and aid in the final development of the conifers; second, to plant all of the first-mentioned class of land with a mixture of white pines and hardwoods; third, to underplant the second class with white pines, making what are hereafter termed "Improvement Thinnings in Young Pine Stands," as the growth of the pines demanded; fourth, to make "Improvement Thinnings in Original Timber Stands," as opportunity permitted; fifth, to clear and maintain a fire guard 40 ft. wide around the outside limit of the reservation, to serve as a protection against fires having their origin on abutting land; sixth, to maintain some of the present, and build necessary additional, internal forest roads 15 ft. wide, making accessible all areas, and acting as secondary fire lines, dividing the entire reservation into lots containing from 15 to 30 acres; and seventh, to clear and maintain a 50-ft. margin along the forested portion

of the flow line of the reservoir, and to plant the inside half of it with white pine and arbor vitæ closely spaced, forming an effectual screen or hedge to keep the greater part of the foliage from adjoining forests from being blown into the reservoir.

Nurseries and Care of Seedlings.

Early in 1898, or about eight years previous to the completion of the reservoir, work was begun upon the preparation of the nursery on the north shore, containing 4.3 acres, and about two years later upon the one on the south shore, containing 3.7 acres. In selecting the sites, attention was given to securing land comparatively level and well drained, composed of moderately fertile, sandy loam, free from weeds and stones. The nursery on the north shore was located on land formerly used for agricultural purposes and contained couch grass in large quantities, making it very expensive to prepare for and maintain as a nursery. The one on the south shore was located within the limits of a large area covered with a stand of fifteen-year-old white oaks and chestnuts in a rather backward state, due to the ravages of forest fires. To prepare this area for nursery purposes, it was necessary to clear, grub, plow and harrow, at a cost of approximately $200 per acre.

Seed Planting. — As the methods adopted in the raising of coniferous and deciduous trees varied somewhat, they will be described here separately, first dealing with the white pines and other varieties of conifers.

During the month of May the area to be used was plowed to a depth of about 15 in., and then leveled up by raking with heavy iron rakes. Beds were laid out 4 ft. wide by 40 ft. long, separated by paths $1\frac{1}{2}$ ft. wide. The seed was prepared by soaking in warm water for about 48 hr. and then covering with red lead to keep off birds and rodents. A "drill board" was used for shaping the drills in which the seeds were placed, consisting of a 1-in. board, 6 in. wide and 4 ft. long (the same as the width of a bed), fitted with a handle on the upper side for convenience in handling, and with two grooved strips about 1 in. square, running lengthwise of the under side of the board at each edge, the centers being 5 in. apart and the groove about $\frac{5}{8}$ in. deep. For convenience in spacing the drills, this tool had at each end an outrigger or gage, consisting of a short piece of lathe, through which was driven a small nail 5 in. distant from the center of one of the grooves.

The seed-planting gang consisted of a foreman and four

laborers, divided as follows: one drillman, two sowers, two coverers. The drillman formed the drills by forcing the molds or grooves of the drill-board down into the soil and rubbing it endwise. The two sowers, one of whom was the foreman, worked from opposite sides of the bed. The seed was placed in bottles fitted with wooden stoppers having a hole of the proper size to permit of one seed passing out at a time. The seeds were dropped on the ridge of the drill and fell into either channel. It was necessary to go over the same length three or four times in order to get a single continuous line of seeds. This method was found to be more economical than that of allowing the seeds to run freely from the bottle, which method sows too thickly. The sowers were followed by one of the coverers who sifted loam over the seed through a common ash sieve of $\frac{3}{8}$-in. mesh until the drills were filled to the general level of the bed. The other coverer completed the planting by consolidating the loam with a board which he laid over the drills and pressed firmly into the ground.

It requires from two to three weeks before the sprouts appear above the ground and, during this time, great care has to be exercised to give the seed the proper amount of moisture. No particular rule can be laid down for this treatment, as it of necessity varies with the climatic conditions. During particularly dry seasons it was found necessary to cover the seed beds with a mulching of leaves and to water this mulch in the late afternoon about every second day. When the beds are mulched, daily examinations are necessary after the first ten days to ascertain when the sprouts have broken through, at which time the mulching should be removed. The ideal condition is that in which nature meets all the requirements and the beds or seeds demand no artificial treatment. Unfortunately, this condition rarely if ever continues for any length of time and it therefore becomes necessary to give almost constant attention to the beds from the time the seeds are planted until the sprouts break through the ground.

During the life of the seedlings in the seed beds (one year) they had to be given considerable care to prevent "damping off." This care consisted principally of screening and watering. Light lath screens about 4 ft. square supported on stakes about $1\frac{1}{2}$ ft. above the surface of the ground were used, being manipulated as the weather conditions demanded. If the season was excessively dry, it was necessary to mulch the seedlings with dead leaves and water about three times a week.

Transplanting. — The seedlings having been in the seed beds one year, the next step was to transplant them into "Transplant Beds," where they were spaced about 4 in. apart in rows 6 in. apart and left from one to three years. In doing this work a gang composed of a foreman, one lifter, three sorters and counters, one pruner, one helper and eight planters was found convenient.

With a common garden spade the lifter removed the trees from the seed beds and they were sorted, counted, pruned and puddled. When the seedlings were taken from the seed beds they were first sorted, separating the strong and weak specimens. Then the long, fine, feathery roots were cut off at the bottom of the stocky part with a butcher's cleaver. The next step was to cover the pruned roots with a thick puddle, prepared by thinning heavy swamp muck to the consistency of thick gruel, after which they were immediately heeled into the ground ready for the planters.

The transplant beds were prepared in the same manner as the seed beds, and the plants or trees were placed in them by means of a common mason's trowel. A good planter should plant about 3 000 trees per 8-hr. day. While in the transplant rows the only care necessary in the summer time was to keep the beds free from weeds, which was done with small hand cultivators. During our treacherous New England winters we are very liable to experience short heavy thaws, which penetrate the ground to a depth of 3 or 4 in. and heave the young transplants out, especially if they were transplanted the previous fall, as the roots do not have time to become well established before being exposed to this severe treatment. When this happens, they must be immediately pushed back into the ground or they will be frozen to death. This work should be done as rapidly as possible because of the liability of a freeze setting in at any time. Very little attention is given while pushing the seedlings back into the ground to keep from bending or crooking the small stems, as the seedlings are being raised for our own use and their value does not in any way depend upon their appearance. So long as nothing is done to injure the growth of the tree, our requirements are met. Caring for the seedlings at such times is given much more attention, however, by nurserymen, as their appearance is quite a factor to their value.

Field Planting. — Our practice has been to divide the work about equally into spring and fall plantings, and time fails to

Eight-year-old White Pines and 6-year-old Maples, planted Spring of 1903. Pines 3 years old, Maples 1 year old.

Seven-year-old White Pines, planted in Grass Land, August, 1905. Four years old.

Nine-year-old White Pines, planted in Pasture Land, Spring of 1902. Three years old.

show any difference in the results obtained. Most of our plans have called for the planting of from 50 to 100 acres of ground in both spring and fall, the former taking place immediately after the frost left the ground and before the trees began to grow, while the fall plantings have generally been made after the fall buds had set, depending largely upon the season. One planting, however, was made in August, and that, although experimental, proved a decided success, in spite of the fact that the trees were four years old and the season immediately following extremely dry. During the following fall these trees suffered some kind of a shock which apparently killed them, the needles all turning brown, but they have since recovered and are now among the finest stands we have.

Planting gangs are composed of a foreman and about thirty men, five of whom are engaged in the nursery preparing the trees for the field in the same manner as for transplanting. The field part of the gang is divided into pairs, one man making the hole for the tree with a common mattock, the other placing the tree and compacting the earth firmly about it. The work is very interesting because of its simplicity and rapidity. The men are lined up in pairs in a diagonal position on the field, the leader with a mattock and the planter with a pail filled with about 100 trees. The first pair are shown a previously established line, stone wall or fence to guide them, while the others in succession, with the aid of one man especially assigned to the duty, plant parallel to and at a given distance from the preceding pair. The spacing in the rows is done by pacing. In the easiest plantings, such as open pasture or light grass land, the leader opens the ground with two strokes of the mattock, the first one being made with the axe blade and the second with the grub blade, cutting the ground just below the top of the first cut. With the grub blade of the mattock in its position at the end of the last stroke, the ground is pulled up and back while the planter places the tree in the hole. While the leader is pacing the distance to and preparing the next hole, the planter compacts the earth about the tree by forcing his heel into the sod. With a well-organized and experienced gang, a pair of men will plant about 2 000 trees in a 9-hr. day, or 1 000 trees per man, at a cost, including the nursery work, of about $3.25 per 1 000 trees.

Great care has to be given during this work to see that the roots of the seedlings are not "root bound" when placed in the ground. The covering of the roots with thick puddle natu-

rally binds them together and, unless they are shaken out before being planted, the growth of the tree will be greatly retarded.

The above description and rate are applicable only to first-class planting areas, the methods varying and the cost increasing according to the nature of the ground. For instance, in heavy grass land it is necessary to remove the sod from an area about 6 in. square, requiring three or four strokes of the mattock, before making the final hole as described above. In sprout land or grown-up pasture the speed is necessarily slower because of the interference of the trees. The maximum cost per 1 000 trees was $7.87.

Thus far we have considered and described the methods adopted in the raising of white pine and other varieties of coniferous trees from the time the seed was sown until they were placed in their final location in the field. Remarkably successful results with these varieties have been obtained, 90 per cent. of the trees placed in the field having lived, and great credit is due the men who outlined and instituted the system. We, as engineers, are frank in admitting that at times we learn fully as much from our unsuccessful ventures as we do from the successful ones.

I now wish to describe the methods pursued in that branch of our forestry work which have largely failed, namely, the raising of hardwoods, the principal varieties of which were maple, oak, chestnut and walnut.

The general method of preparing the ground and seed was similar to that used in sowing the conifers, except that the different varieties of seed were soaked for varying periods, dependent upon the variety and quality of stock. The drills into which the seed were sown ran lengthwise of the beds instead of across and were single drills 6 in. apart instead of double ones. After remaining in the seed beds for one year, they were transplanted directly into the field after being culled, pruned and puddled in a manner similar to the conifers. Experience and time revealed the fact that the hardwoods thus planted were, almost to a tree, dying and, as the nursery was at this time filled with hardwood seedlings, it became necessary to change our method if we wished to obtain satisfactory results. The reason for their almost complete failure was first attributed to the age (one year) at which the seedlings were transplanted into the field, so it was decided to transplant the seedlings into transplant beds, having the rows 12 in. apart with the trees 6 in. apart in the rows, thereby giving sufficient room for de-

velopment for at least two years more. In transplanting to the transplant beds, the same general treatment was given the seedlings as described in transplanting the conifers. During the season following transplanting, when the only care given was to water and keep the beds free from weeds and witch grass, the trees seemed to prosper and pick up finely, but the next spring the fact was revealed that a great many (perhaps 33 per cent.) were dead, and each succeeding spring found us with fewer trees, and these very weak, sickly specimens. These facts led us to believe that the failure of the one-year-old hardwood seedlings planted in the field was not wholly due to their age, but more to their treatment and the soil in the nursery. A careful study of this soil, the condition of the roots in the fall and spring, and the treatment given the seedlings, led us to believe that the true cause of this failure lay in the character of the soil.

The kind of soil recommended for the nurseries was, as stated previously, well-drained, moderately fertile, sandy loam, free from weeds and stones. After due consideration and study, the nursery on the north shore was established and the raising of pine seedlings begun. During the early stages it was discovered that the soil in this nursery was not particularly well adapted to the needs of the pines; so when the time for planting hardwood seeds arrived, this nursery was chosen for them and a new one established on the south shore for the raising of the pines. While the nursery on the south shore was an ideal one for the pines, it did not seem at all adapted to the requirements of the deciduous trees, while the soil in the other nursery did; therefore they have been used for conifers and hardwoods respectively. The continued working of the soil in the hardwood nursery has revealed the fact that it contains a large proportion of shale, and it is to this that we attribute the failure.

During the winters since the hardwoods were planted, there have been one or two extremely heavy thaws which have partially uprooted the seedlings and in so doing stripped the small fibrous growth from the delicate tendrils, thus robbing them of their means of securing nourishment from the soil, and weakening them to such an extent that they were unable to withstand the freeze which followed. This theory is borne out by the fact that the trees having one main tap root (ash and locust) have withstood the exposure and thrived surprisingly well.

Composition of Plantings. — Thus far we have considered

and explained the work so far as the methods of raising forest trees from seed and planting them into the field are concerned. Now let us deal with the makeup or composition of the seedling stands.

The original condition of the area to be treated being so varied, it was necessary to vary the composition of the artificial stand to meet the requirements of the individual lot. In the main, the plantings comprised white pines planted 10 ft. by 10 ft. apart, using oaks, chestnuts and maples as fillers, making the final stand with trees 5 ft. by 5 ft. apart, the theory of this composition being that the hardwoods, growing so much faster than the pines, would thrash their young, tender limbs, thereby forcing them to grow upwards and develop a long, straight, clear log. This type of planting required 435 pines and 1 307 hardwood trees per acre and was used in arable, open pasture and light sprout land.

In the thick sprout and young, thinly grown timber land, the pine seedlings were used to underplant the sprouts and interplant the open areas of the timber land. No set rule could be established for the spacing in this type of planting, as it varied with the existing growth. It would be safe to estimate from 500 to 800 trees per acre.

The first plantings were made during 1902, and from then up to the time that the failure of the hardwoods (1906) was discovered, the mixed type of planting was used. Since that time no hardwoods have been planted and the pine seedlings have been spaced 6 ft. by 6 ft. apart in the field, this close spacing being adopted so that the limbs might thrash and kill each other, thereby obtaining the same results as with the mixed stands. This spacing required 1 210 trees per acre.

Improvement Thinnings.

We are told by forestal experts and advocates that the pines need no attention after planting in the field until such time (about fifteen years afterwards) that the first thinning is necessary. This is true only so far as it deals with the planting of arable and open pasture land. One of the main arguments in favor of reforestation is that sprout and scrub lands may be converted into paying timber land by simply raising and planting the young trees. While I would not go on record as making any statement detrimental to the growth and advancement of this great industry of forestry, which is one of the foremost questions before our country to-day, yet I believe that, for the

good of its development, it is necessary that this article contain all the facts as we have found them.

A large part of our reservation was covered with sprout and scrub growth, which has been and was originally intended to be underplanted with pines. About the only requirements for a vigorous growth are plenty of light and fresh air, and we all know, if only from occasional observation, that neither of them is found under such a ground cover. When planted in this kind of land, the pines grow up in a rather delicate condition, until their tops encounter the low-lying limbs of the surrounding growth. At this stage it is absolutely necessary to give them assistance if they are to survive. This we have found can be done for about $6.00 per acre, the method being to cut out all growth which is in any way, at this time or within the next few years, liable to stunt or kill the trees. The wood cut at this time has very little value even as cord wood on account of its small size, so it has been piled in windrows between the pines and left to rot, or disposed of for pea brush.

In doing this work due care is taken to preserve all valuable specimens of trees and to leave sufficient fillers of any nature whatever which will act as crowders to the pines.

Our one aim in all branches of the work thus far described has been to secure ultimately a sound, healthy stand of pure white pines, having from 250 to 350 trees per acre.

As considerable of the reservation was originally covered with timber stands varying from fifteen to fifty years of age, which had been left to take care of themselves for years past, it has been our practice to make improvement thinnings in them by cutting out the poor, weak specimens, and such of the hardy ones that were overtopping or crowding the young vigorous growth. In a stand of twenty-five-year-old maples and chestnuts, intergrown with gray birch, a thinning such as described above, which included the cutting out of all the birches, was made at a cost of $28.50 per acre. There is considerable revenue derived from the sale of cordwood made at this time, which has, under the most favorable conditions, paid for the labor. Undoubtedly additional thinnings will have to be made from time to time, taking out the weak and overtopping specimens, which in all probability can be done at a profit. By this method the maximum returns per acre will ultimately be secured.

Fire Protection.

Among the greatest dangers to the forests are fires and, in order to prevent their spreading to or from abutting property,

and to provide a line of defense on which to fight them, a "fire guard" 40 ft. wide has been cut around the entire outside limit of the marginal lands of the reservoir. There is also a network of "forest roads" 15 ft. wide throughout the reservation, which acts as supplementary fire protection. The brush and weeds are cut from these two protective systems once every year.

A double furrow has been plowed along that portion of the fire guard where there was no stone wall to check the advance of creeping fires from neighboring property.

On holidays and Sundays, during the dangerous seasons of the year (early spring and late fall), men armed with fire extinguishers patrol the reservation to further protect it from the ravages of forest fires.

Thus far no serious fires have occurred, though several have started which would have caused great damage but for the effectual protection given.

Reservoir Marginal Screen.

In order to have an effectual screen along the forested portions of the shore of the reservoir, which would prevent the foliage from the deciduous trees from being blown into the reservoir, three rows of white pines spaced 6 ft. apart each way, and two rows of arbor vitæ 2 ft. apart, trees 3 ft. apart in the rows, have been planted on the back half of the 50-ft. reservoir margin. The greater proportion of the arbor vitæ have failed, probably because of having been planted in the field when too young (two or three years old) to endure the severe exposure which prevails along the shores of the reservoir.

At the time of sowing the arbor-vitæ seed, a much larger quantity was used than was needed for this purpose, so the seedlings which remained after the planting was done have been transplanted into transplant beds in rows 12 in. apart with the trees 6 in. apart in the rows. These trees have now been in the transplant beds two years, during which time they have been pruned once, with the result that we now have available a sufficient number of strong hardy specimens with which to replant the entire 32 miles of flow line. This will require about 113 000 trees, spaced 3 ft. apart in rows 2 ft. apart, breaking joints, so to speak.

The table following shows that it costs about $15.40 per 1 000 trees, or $19.20 per acre (1 390 trees per acre), to raise the trees from seed, prepare, plant and protect the lands planted

Table of Work accomplished to December 31, 1908.

Total area of nurseries	8.0 acres
Total area planted	1 330 acres
Total number of trees planted: coniferous	948 000
deciduous	902 000
Total length of reservoir margin planted	32.0 miles
Total length of fire guard cleared and maintained	20.8 miles
Total length of forest roads cleared and maintained	30.0 miles
Planted area thinned	488 acres
Original timber stands thinned	209.0 acres

Table of Costs.

Wage rate, $1.75 per 8-hr. day.

Nurseries:	
Clearing nursery on south shore	$200.00 per acre
Maintenance of nursery, first year seedlings	$1.50 per 1 000 trees
Maintenance of nursery, second and third year seedlings	$1.75 per 1 000 trees per year
Plantings:	
Clearing areas preparatory to planting	$4.00 per acre
Transplanting seedlings from nursery to field	$5.25 per 1 000 trees
Transplanting seedlings from nursery to field,	$5.50 per acre (6 ft. by 6 ft. planting)
Improvement thinnings:	
Among planted trees	$6.00 per acre
In original timber stands	$20.00 per acre
Fire Protection:	
Clearing marginal fire guard 40 ft. wide	$150.00 per mile
Maintaining marginal fire guard	$27.00 per mile per year
Clearing and grading forest roads 15 ft. wide	$120.00 per mile
Maintaining forest roads	$8.00 per mile per year
Maintaining fire patrol	$100.00 per year

Reforestation. Summary of Costs on Planted Pine Stands.

Wage rate, $1.75 per 8-hr. day.

Item.	Per 1 000 Trees Planted.	Per Acre Planted.
Preparing nurseries	$0.40	$0.60
Seedlings (1 year)	1.50	2.25
Transplants (2 years)	3.50	4.50
Preparatory clearing	3.00	4.00
Field planting	5.25	5.50
Clearing 40-ft. fire guard	0.75	1.00
Clearing 15-ft. forest roads	1.00	1.35
Maintaining 40-ft. fire guard (per year)	0.14	0.19
Maintaining 15-ft. forest roads (per year)	0.06	0.09
Maintaining fire patrol	0.02	0.03
Improvement clearing	4.25	6.00

through the time of the final planting in the field; that it costs about 22 cents and 31 cents per year respectively to maintain efficient fire protection; that in sprout and scrub land it costs about $4.25 and $6.00 respectively for an improvement thinning, which will probably have to be made twice during the first ten years, after which time the trees should care for themselves.

The credit for the marked success of this work is here given to Dr. Henry P. Walcott, of the Metropolitan Water and Sewerage Board, and president of the Massachusetts Forestry Association; Frederic P. Stearns, chief engineer of the Metropolitan Water Works during its conception and the greater part of its development; and Hiram A. Miller, who, while engineer of the reservoir department of the Metropolitan Water Works, had charge of the planning and beginning of this work.

Conclusions.

While the methods adopted have, in general, given very satisfactory results, some lessons have been learned which should be of considerable assistance to promoters of similar schemes.

First: As stated above, the character of the soil in the nursery used for the raising of hardwoods seems to be the cause of their failure, and, therefore, it would seem to be a warranted expense, when selecting nursery sites, to employ an expert in soil analysis to determine the location for the nurseries required. The United States government has such men whom it is only too glad to furnish at little or no expense to the owner or promoter.

Second: The order in which the various classes or types of the land were planted does not, at the present time, seem to have been entirely fortunate. The first land planted was the arable and pasture; second, the light sprout; and last, the thick sprout, scrub and thin timber land. If left to my judgment, based as it is on the lessons learned in the development of this reservation, this order would in a great many cases be reversed. In so doing the stands requiring thinning within the first five years would be planted first, and those requiring little if any thinning for at least fifteen years would come last. Of the type planted first, the heavy grass land proved especially hard for the pines, for during heavy snowstorms the long dead grass became matted down upon the small trees, leaving them covered with a heavy thick mat through which very little light could penetrate, or the young trees force themselves. On such areas it

was necessary to mow around the young trees or, by means of a common dung fork, to break open this mat and free the tree. If these areas had been mowed for a few years before planting, the grass would have naturally run out and become so weak and thin that it could have done no harm to the seedlings. This matter of the order in which various classes or kinds of land should be planted is, it seems to me, a very important one, and the person who, without experience, plans to take up the work of reforestation would do well to consult the state forester, who has a competent corps of assistants ever ready to give suggestions and help in making up planting plans.

While the development of the area planted has not advanced far enough to allow of any estimate being made of the ultimate cost of the final quantity of lumber to be marketed, it has proven beyond a doubt that a scheme of reforestation along the lines described can be successfully carried out without more than slight assistance from experts; for, aside from having the general policy outlined, this work was planned and carried out by men inexperienced in this work.

Another fact which, to say the least, has not been beneficial to the work is that the personnel of the force doing the work, from the engineer or forester in charge down through the ranks, has so changed with the advance and completion of the work on the reservoir that there now remains but one man, a foreman, who was on the work at its beginning.

These facts only go to prove that with a small amount of professional advice and an intelligent study of nature, satisfactory results can be obtained.

Some people may censure the promoters of this work for entering upon a project which would be in part experimental and which would require the expenditure of considerable money before any returns would be received therefrom, but by those who have the interests of forestry at heart they will be commended for thus having taken steps to turn their own waste and valueless land to the most economical good, creating a shelter for the native wild animals and birds and beautifying an otherwise rank, repulsive and unsatisfactory wilderness, besides establishing a source of reference where all those interested either in forestry pure and simple or forestry as a branch of our large water supplies may look for information which we hope will materially aid in the final reforestation of our own great country.

DISCUSSION.

Mr. Arthur A. Shurtleff.* — I will not weary you with an account of trees considered from a botanic point of view, or even from my own viewpoint of the landscape architect, because I suppose these viewpoints would not interest your Society at this time. I wish rather to consider some of the engineering problems, as they may be called, which the trees themselves are obliged to solve from gale to gale and from drought to drought and under difficult light conditions. The struggle for life among trees is so keen that the factors of safety between life and death are with them often very small. A knowledge of these factors of the living tree is often important to the engineer who has control of grading operations or of the levels of water near trees which are to be reckoned with as elements of profit or loss either in dollars or in landscapes. The half hour which you have allotted me for my remarks is sufficient to outline a few of the relations between the tree's problems and the problems of the engineer.

Trees are structures in an engineering sense; their trunks are designed to bear the direct compressive stress of the canopy of branches, whether laden with foliage or with ice, and this stress is distributed at the ground by a crown of roots. In soft marshy soil this root crown is spread out to a remarkable extent to reduce the foundation pressures to the lowest terms. Under lateral wind pressures tree-trunks act in a more important structural capacity as cantilevers, holding the tree erect by the tensional resistance in the outer roots of the crown and by complicated stress of all kinds in the crown itself. The shallowness of the root system makes the problem of stability in heavy gales a serious one for trees standing exposed in open land. Trees sheltered from the wind in groves, however, are not subject to such stresses and their roots are not developed consequently to withstand lateral trunk loads of a serious kind. Such trees, if freed from their neighbors (by radical thinning operations) and exposed to the buffets of the wind, are liable to be uprooted.

Of far greater importance to the tree than mere agents of stability, the roots serve as providers of moisture. A large tree evaporates hundreds of pounds of water from its leaves daily in summer time, and it evaporates tens of pounds from its branches, twigs and buds in the dry cold weather of winter. This water is taken from the soil. In our climate at those seasons when leaf

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* Landscape architect, Boston, Mass.

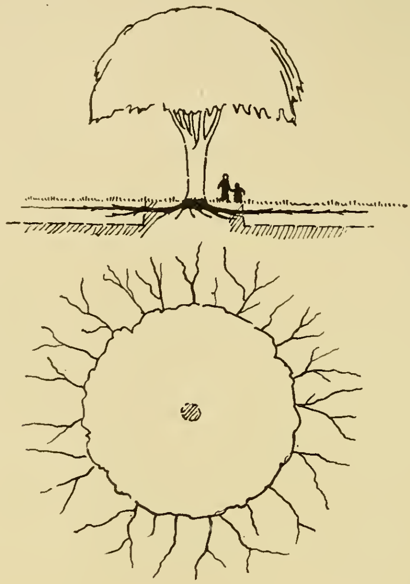
evaporation is at its height, water in the soil is generally least and the roots are taxed to the utmost to secure it. Demands of this kind require much greater extensions of the root system than are required for the stability of the tree against the wind, and they necessitate minute threadlike subdivisions of this great root system to secure intimate contact with a large volume of moist earth. Trees sheltered from the sun and from drying winds in groves evaporate less water at all seasons than trees exposed in the open. As a consequence they are not highly developed as water getters. Such trees, if freed from their neighbors by thinning operations and exposed to the sun, are liable to be dried to death not alone in summer, but in winter.

The relation of trees to their accustomed water conditions is a very delicate one: a tree growing in a swamp will usually die if the swamp be drained suddenly, and a tree growing upon a dry gravelly upland will usually die if its moisture supply be suddenly increased by the water of a new reservoir or pond. Such water may reach the roots of the trees through a distance of five or ten feet vertically by mere capillary action among the particles of soil in a way to dangerously threaten the tree's life. Water actually brought in contact with the roots by direct immersion permanently is almost certain to be fatal under these conditions if it submerges even a small part of the root system.

Gravel or loam, if spread thickly about the crown of a tree, also tends to alter the soil-water conditions about the roots and may either improve or injure them. Trees like the willow or maple, which grow readily in wet ground, will endure greater filling about them than trees like the pine which thrives naturally in light dry soils. It will be seen that the mere provision of a ring of stones forming a dry well around the trunks of trees which are filled upon affects only in a very minor way the main body of the filling upon the roots. Wells should be provided to prevent the rotting or constriction of the bark, but they are only one of the minor factors determining the life or the death of a tree subject to filling.

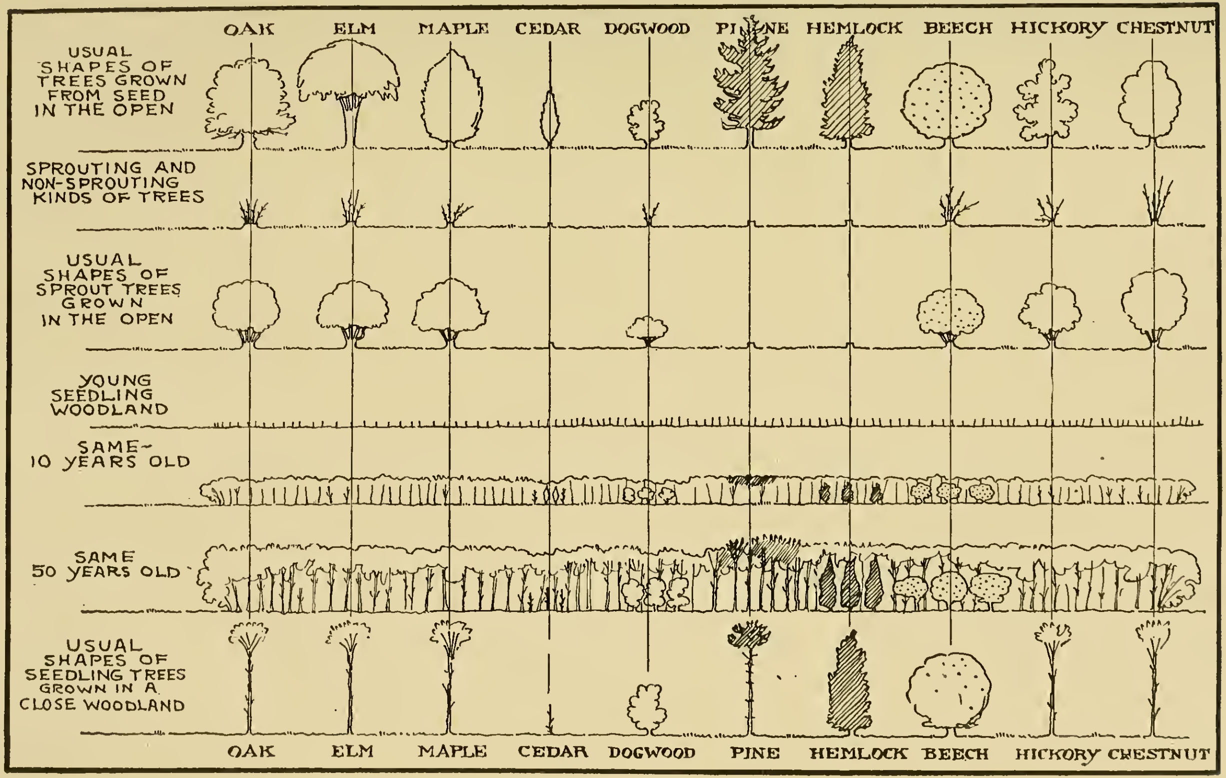
The accompanying figure represents in typical plan and section the root and foliage system of a free standing tree. The great extent of the root system and its nearness to the surface are noteworthy. Evidently the stability of this tree would be seriously threatened if the soil and roots were stripped as indicated by the dotted line, even were a tap-root present. Trees are frequently mutilated in this manner, nevertheless, in the

course of grading operations under the belief that they will survive such treatment. The water-getting capacity of a tree shorn in this manner of its roots is evidently reduced to an absurd ratio with the demands of the foliage evaporative area.



No formula may be followed with satisfactory results in excavation work in the vicinity of trees except the general warning, "Keep off." When this rule cannot be observed, the disturbance of the soil should not approach nearer the trunk than the radius of the spread of branches. Even within these limits the ground about the tree should be freely watered in dry weather until new roots have formed in the replaced top soil. At the same time the evaporative area of foliage and branches should be reduced by pruning proportionate to the curtailment of the root system. Evidently the conditions under which most engineering works are undertaken would not permit these watering and pruning operations to be carried on. In such circumstances, trees which are liable to die without these safeguards should be cut.

The remarkable power possessed by many of our native trees, enabling them to reproduce themselves at once by vigorous stump-sprouting, when felled or seriously burned, is of especial interest. This vigor or replacement or "maintenance" has no parallel, I think, in engineering contrivances devised thus



OAK
ELM
MAPLE
CEDAR
DOGWOOD
PINE
HEMLOCK
BEECH
HICKORY
CHESTNUT
USUAL SHAPES OF TREES GROWN FROM SEED IN THE OPEN
SPROUTING AND NON-SPROUTING KINDS OF TREES
USUAL SHAPES OF SPROUT TREES GROWN IN THE OPEN
YOUNG SEEDLING WOODLAND
SAME–10 YEARS OLD
SAME 50 YEARS OLD
USUAL SHAPES OF SEEDLING TREES GROWN IN A CLOSE WOODLAND
OAK
ELM
MAPLE
CEDAR
DOGWOOD
PINE
HEMLOCK
BEECH
HICKORY
CHESTNUT

far by men, but the trees have devised ways and means to accomplish it in order to succeed in their struggle for existence. An oak may be felled four times or more in a century and still continue to reassert itself by strong sprouts from the old trunk or its remnants. Sprouting trees (or coppice) of this origin differ in many respects from seed-grown trees, and their behavior has an important bearing upon the rate of growth and the makeup of new woodlands derived from the destruction of old ones. This subject may be reviewed conveniently by reference to the accompanying page illustrating the habits of ten of our more common New England trees.

Trees growing singly in open land, with unhindered light and air on all sides, assume distinct species characteristics. Under these conditions the oak, the elm and the pine display their individual forms which are as clearly distinguishable as the difference in their leaf outlines. (See the first row of the illustration.) If these fine trees are felled to the ground, all of them, with the exception of the cedar, pine and hemlock (reproduced only by seeds), will send out sprouts from their trunks as indicated in the second row. In the course of time these sprouts will become large, but usually unsound, trees, having multiple stems like a clump of celery. In this new condition the trees lose a large share of the individual shape of the species and are to be distinguished from one another rather by their leaves and bark and habit of stem than by their foliage outlines. Trees of this multiple kind grow rapidly and lose great quantities of suppressed stems in the form of dead wood. Extensive tracts of such sprout growth rapidly become impenetrable thickets and, unless properly cleared and periodically thinned, are the source of disastrous wood fires.

The obliteration of the characteristic foliage forms also takes place among most trees, even in a primeval condition, when they stand so closely together that their side branches are killed by overshading. Shade of this kind has little effect, however, upon "tolerant" trees like the hemlock, beech and flowering dogwood. The illustration indicates a group of young seedlings of ten kinds, including tolerant, intolerant, sprouting and non-sprouting varieties closely planted to form beginnings of dense woodland. (See the fourth row of the illustration.) After a period of ten years this miniature forest may be represented by the diagrams in the following row. At this stage many trees have died from overcrowding and the energy of all the intolerant trees is directed to as rapid and upward growth

as possible in order to hold their tops above the impending shade threatening upon all sides. A section of such a woodland at the end of a period of fifty years or more is indicated in the diagram.

It will be seen that only those trees tolerant of shade, the hemlock, beech and dogwood, have retained their characteristic form, while all the others have become slender stems studded with dead side branches and crowned with a mere tuft of foliage. In this struggle the slow-growing cedars have been unable to keep pace with the upward race among the more rapidly growing trees and they have died largely for want of light. The mortality among all the trees in the contest, however, has been great, and those individuals whose foliage canopies were squeezed out of the sky line by more robust trees adjoining them have died in legions from the effects of darkness. The series of ten outlines in the last row indicate upon a larger scale the effect of this struggle for life upon the same trees shown in the first row; only the tolerant trees retain their characteristic species form. Dense sprout growth of oak, hickory, ash and chestnut exhibit, of course, similar characteristics upon an exaggerated scale and frequently lack the non-sprouting evergreens, pines and hemlocks. This is the type of monotonous woodland which the engineer usually has to deal with in our vicinity, and it frequently lies within his power by well-managed thinning operations to assist the wasteful processes of nature and hasten the development of fine timber.

In the undertakings of the Metropolitan Water and Sewerage Board in the neighborhood of Boston, it has been a policy followed for a long period of years to carry out systematic forest improvements of this character in all woodlands under the Board's control. The results of this work have justified the policy. These improved woodlands have been kept comparatively free from fires and they contain some of the best standing timber in the vicinity of Boston, although at the beginning of this caretaking work the tracts were fire traps and in sore need of attention for the health and vigor of the trees.

Mr. Frank William Rane.* — I assure you it gives me great pleasure to be here, and I have been entertained very much in hearing the reading of the papers and the speeches that have followed. However, I think it is pretty late for the state forester to start in. But I shall be happy some time to come

* State forester of Massachusetts.

before this organization and outline at least some of the work we are attempting along the line of state forestry in Massachusetts. I have been here two and a half years, and I assure you I have found plenty to be done in this line. Fortunately for us, forestry is in the air to-day and everybody is interested. I am partly a Westerner; was born and raised in southern Michigan. When I came to New England in the fall of 1895 there wasn't very much use in talking forestry. I was as much interested in it then as I am now. I pulled one end of a crosscut saw as a boy in Michigan and I know the " plagued " trees, as we used to call them, don't drop over and die very readily if you give them a chance.

In Massachusetts to-day the root of the whole problem is how to get rid, in the first place, of all these fires. Fires are running rampant all over this old Bay State every year. It is worse thus far this year than last, and it was bad enough last. Living in the woods in this new country — burning down the trees and piling them up to get rid of them in order to get a livelihood from agriculture has been a common practice until recent years. It is time we should look at this thing from a very broad standpoint, adopting a broad, constructive policy, with the idea of future usefulness. The photographs that we have seen of foreign conditions are examples of nothing more than history repeating itself. The older countries of the Old World have gone through exactly the stages we are going through now, and it is human nature never to heed anything until you are right up against it, so to speak. In Massachusetts we had primeval forest, a natural forest country. If you and I were to move out to-morrow, it would grow up to a wilderness. Trees will grow. Just give nature a chance. White pine is a veritable weed all over this state, and in many sections the chestnut is as well. At Amherst one man in sixty years' time has taken off a 50-acre tract $500 an acre of chestnut growth. He showed me alongside this tract a tract where the fire ran over it when he was a boy. It caught fire from a workman's pipe. They were able to extinguish it after it had run over just half the mountain side. That half where the fire ran over fifty years ago is comparatively worthless to-day, a loss of practically two generations of sprout growth. It burned off the humus, the organic matter, spongy conditions for holding moisture and leaf-mold there.

Now as to the question of fires. How are we going to regulate them? I have been sitting up nights thinking about and discussing the question and going before committees of the

legislature and working in other ways. People are willing to take hold. The people are going to do something, if we will take hold and lead the way. Our people have gone abroad and seen these things, but have not paid much attention. It shows how we are trending. The prices of manufactured products are going up. Touch the pocket-book of the average American and he begins to take notice. Now is the time we can do something by virtue of the fact that forest products are worth something. What are box-boards? When I was a youngster, beautiful white pine with hardly a knot in it used to sell for $10 to $15 a thousand in Michigan. That seemed an outlandish price when my father had to pay it. Clear Michigan pine to-day is worth over $100 a thousand. Box-boards shipped to Boston bring anywhere from $16 to $20 a thousand. Why is pine lumber going up? It is simply a question of supply and demand. Old cabbage pines, the original seed trees, are cut down to-day for box-boards. It is just an economic problem. We have heard the esthetic side. The ideal Massachusetts of the future is to have the lands devoted to agricultural crops producing maximum crops, then the remaining lands, composing three fifths of the acreage of the state, 2 500 000 or 3 000 000 acres, capable of producing forests utilized for that purpose.

Studies we have made show that these lands may average $5 or more per acre per year when set to white pine. Even pasturage, where we are turning our cows upon the land and getting comparatively little from them, will not rent for much over $1 an acre. The whole thing is a question of business knowledge and systematizing. With our present methods of handling Massachusetts lands, putting portable mills upon them and skinning the lands and then burning them over, we are practicing a backward policy. Lands worth 50 cents to $5 an acre, that are capable of producing forest products as already mentioned, mean something like $12 500 000 to $25 000 000 per year coming into a state like Massachusetts under normal conditions of ideal forestry. Without trespassing further at this late hour, I simply desire to say that a problem like this I am sure will appeal to a body of civil engineers as a matter of importance.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1910, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER, "CEMENT AND SAND FOR CONCRETE."

(Volume XLIII, Page 185, November, 1909.)

Mr. J. P. Snow. — Referring to discussion on "Cement and Sand for Concrete," in Journal for November, it occurs to me that a good criterion of cleanness of sand is the freedom of its grains from sticking together.

The sand may be coarse or fine, but if each grain admits of being wholly covered with a film of cement, the mortar will have the strength of the cement. If, however, several grains adhere together strongly enough so that they are not separated by the process of mixing the mortar or concrete, it is evident that the spot in the mass where this lump is will be no stronger than the lump itself. The material causing the sand to stick together may be clay, a film or silt, organic matter, oil or chemicals, but if effective enough to hold the grains together till the concrete is placed, it will cause a weak nucleus in the material. A magnifier will greatly assist in determining the qualities of sand.

OBITUARY.

William Parker.

Member Boston Society of Civil Engineers.

William Parker, a valued member of this Society, died of typhoid fever, in Boston, on the 30th of September last, after an illness of about a month.

He was born in East Bridgewater, Mass., August 22, 1861, and was educated at the high school in that town. He was first employed in the fall of 1880 in the office of Thomas Keith, a land surveyor located at Brockton. After spending a year in Mr. Keith's office, he found employment as a rodman on a preliminary survey for a railroad between Boston and New York, to be known as the New York & Boston Inland Railroad.

In 1882 he entered the service of the New York & New England Railroad Company at Boston, remaining with that company until August, 1884. During the latter portion of his service there he had charge of a party on the construction of a second main track. During the balance of the year 1884 he found employment in the office of Mr. Alexis H. French, town engineer of Brookline, Mass.

In March, 1885, he began his service on the Boston & Albany Railroad, in the office of the division engineer, located at Springfield, Mass., and continued in the service of that railroad up to the time of his death, serving successively as assistant division roadmaster, from March, 1887, to November, 1887; then as division engineer up to November, 1907, and finally as principal assistant engineer, up to his death.

He became a member of this Society, March 21, 1888, and manifested great interest in its welfare. On February 16, 1898, he contributed a paper to our transactions on the "Abolition of the Grade Crossings on the Main Line of the Boston & Albany Railroad in Newton, Mass.," which was published in the Journal of the Engineering Societies for August, 1898.

In 1900 he joined the American Society of Civil Engineers.

He was married, in 1885, to Abbie A. Stoddard, of Douglas, Mass., who survives him.

Personally, Mr. Parker was an example of the highest type of manhood, a Christian man in every sense of the word. His success in life was due to his own exertions and his own sterling qualities and virtues. Although he was by nature modest and retiring, yet all who came in contact with him found him an agreeable companion, and soon learned to appreciate his worth. His ideals were high, and he was remarkably successful in attaining them.

When at work he went into it with a will, and gave it his whole strength. There was no such word with him as "fail." He possessed a remarkable faculty of observation. Nothing, however insignificant, escaped his attention. He was methodical and precise in all that he undertook. He was an engineer of excellent judgment. He was an earnest, painstaking and conscientious worker, whose achievements were creditable and enduring.

Doubtless he worked too constantly, and would have survived longer with more relaxation.

He left behind him an unblemished reputation, tender memories and an example which is an inspiration to us all.

WALTER SHEPARD,
HERBERT C. KEITH,
EDWARD A. HASKELL,
Committee.

Charles Darwin Elliot.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

CHARLES DARWIN ELLIOT, son of Joseph and Zenora (Tucker) Elliot, was born in Foxboro, Mass., June 20, 1837. He was educated in the schools of Foxboro, Wrentham, Malden and Somerville, and at the Hopkins Classical School of Cambridge, where he remained until 1855.

His engineering education began in the office of Stearns & Sanborn, in June, 1855, where he remained until July, 1859, most of his time being devoted to work on locations, bridges and construction for the Fitchburg Railroad; a part of it for the city of Charlestown on sewers and other city work and on the Cambridge Water Works.

In July, 1859, he was appointed principal assistant under

George L. Richardson, civil engineer, on the street surveys for the town of Somerville, Mass., and engaged in this work during 1859–1860. During 1860–1861 he was in partnership with T. Edward Ames, civil engineer. They had offices in Winnisimmet Square, Chelsea, and in Somerville. In 1862 he was in the office of J. G. Chase, civil engineer, later city engineer of Cambridge, Mass., and was most of the time engaged in running levels, establishing benches and making plans for sewers; also making preliminary studies and plans for the Charlestown Water Works.

During the year he drew, for Gen. Henry L. Abbot, of Cambridge, Mass., a plan of the siege of Yorktown, Va., from notes by General Abbot. The execution of the plan so pleased the general that he procured for Mr. Elliot an appointment from the War Department as assistant topographical engineer.

He left home for the front the day before Thanksgiving, and in December was assigned to the Nineteenth Army Corps, where he served successively under chief engineers Gen. Henry L. Abbot, Major D. C. Houston, Capt. J. C. Palfrey and Capt. Franklin Harwood, and was attached to the headquarters of Generals Banks, Grover, Franklin, Cameron and Asboth. On December 4, 1862, he sailed from New York on the transport *North Star* with Gen. N. P. Banks's headquarters' staff for service among the swamps and bayous of southern Louisiana, in a campaign the object of which was the opening of the Mississippi River to navigation by the Union forces and separating the Confederacy from its rich sources of supply in Texas.

One of the first expeditions in which he took part was a demonstration in March, 1863, against Baton Rouge, with the idea of threatening Port Hudson and thereby assisting Farragut to pass the rebel batteries on the lower Mississippi. On April 12 and 13 he was engaged in the campaign in the Bayou Teche country and took part in the battle and capture of Fort Bisland, and in the occupation of Opelousas on the 20th, where he took charge of the Confederate land office, in which were many plans of the surrounding country that were of great value to the Union forces.

On the night of the 22d of May, 1863, the investment of Port Hudson was completed. Before reaching Alexandria on the march to Port Hudson, Mr. Elliot was taken ill with pneumonia. It was thought by the army surgeon that he could not live. He recovered, however, and served through the siege, in which five of the assistant engineers in a total of twelve were either killed or wounded.

After the capture, Mr. Elliot remained at Port Hudson until the 26th of July in charge of the engineer office and engaged in the preparation of the official plan of the siege. He was very expert in plan and map making, and this plan of Port Hudson was beautifully executed and one of which he was very proud.

In September he took part in the unfortunate Sabin Pass expedition as engineer officer under Major-Gen. Wm. B. Franklin. Beginning October 3 he took part in a second campaign under General Franklin along the banks of the Teche, the object being the occupation of Texas by an overland route. This campaign was also abandoned and Mr. Elliot returned to New Orleans, where he was taken ill with malarial fever, the results of which affected his health for many years.

He was detailed for service at Fort Butler on the Mississippi River in November and to the Department of West Florida under General Asboth in December. He was appointed engineer officer to Gen. Cuvier Grover early in 1864, to take part in a proposed campaign against Mobile, and was given charge of construction of field fortifications in east Louisiana. He received from General Grover a personal letter commending him for his faithful and efficient service in designing and constructing the fortifications at Madisonville on the east shore of Lake Ponchartrain. Before the campaign could be carried out, a portion of the troops were ordered to Virginia to assist General Grant, but previous to this, in March, he was engaged in the Red River expedition, another attempt to occupy Texas by land, with water communication by way of Red River. He was halted, however, at Alexandria by his old enemy, the fever, and here ended his Civil War service. He returned in April, 1864, to his father's farm at Foxboro, Mass., where he remained for nearly a year, enjoying poor health, as he would say.

He twice received special mention for meritorious service in the field and was twice offered a commission: first in the corps of colored troops in 1863 and in the Loyal White troops of Louisiana in 1864, both of which he declined.

In January, 1865, he removed to Cambridge, Mass., and entered the office of Wm. S. Barbour. During the year he was engaged in making railroad surveys from the limestone quarries to the limekilns at Rockland, Me.

During 1866 and 1867 he was engaged in the manufacture of paper collars and cuffs. Much of the machinery used was either invented or improved by Mr. Elliot, and all the patterns

and designs used were his own ideas and from his drawings, imitating elaborate lace and embroidery effects. He was possessed of considerable inventive faculty; besides the machinery previously mentioned he planned and made a working model for a lawn mower previous to the Civil War and long before this article was known to commerce. Another of his practical ideas, which antedated considerably its actual adoption by the War Department, was that of plate armor for ships. He invented, shortly before the introduction of ironclads, a device for drawing copper bolts from ships so as to preserve the bolts; this device was patented. Still another practical idea of which he talked, as early as 1869 or 1870, was that of perforated pipes to be built into walls and partitions to be connected with the hose in case of fire. This has since been patented by some one else.

He removed in the spring of 1867 to Brookline and in the autumn of the same year to Newton Center, Mass.

In 1868 he was in the office of J. F. Fuller, engineer for the Boston Water Power Company, engaged upon sewers and in other engineering work in the Back Bay. He formed a partnership in 1869 with Wm. A. Mason, civil engineer, of Cambridge, and during 1869–70 was engaged in general engineering, street and land improvement, and the construction of the famous Beacon Trotting Park in Allston, now occupied by the Boston & Albany Railroad roundhouse and yards.

In April, 1870, he removed from Newton Center to Cambridgeport and in December of the same year returned to Somerville, where he opened an office. Previous to and during the winter of 1870–1871 he attended afternoon and evening lectures on chemistry and engaged in laboratory work in mechanical and mining engineering at the Massachusetts Institute of Technology.

During 1871–1872 he was chief engineer of the Arlington Water Works, and in 1872 was elected the first city engineer of the newly incorporated city of Somerville. In 1873 he was engaged in private practice and employed by Middlesex County in the widening of Somerville Avenue and the relocation of the horse railroad from the side to the center of the avenue and the adjustment of the damages incurred by the widening. He was reappointed city engineer in 1874 and 1875. Among the important engineering works carried on under Mr. Elliot as city engineer was the construction of the newly widened Somerville Avenue; the construction of the Somerville part of the sewerage system for abolishing the Miller's River nuisance, which

involved the construction of an 8-ft. sewer in Somerville Avenue and the filling of Miller's River by digging off the top of historic Prospect Hill, and the construction of Broadway Park.

From 1876 to 1880 inclusive he was engaged in general engineering, as expert in sanitary, hydraulic and railroad work.

During 1881 and 1882 he made surveys and plans for one of the numerous Cape Cod Canal schemes. Following this and until 1890 he was in charge of and engaged in making insurance surveys in Boston and vicinity and in Lynn. In 1887 he was made agent for the estate of James C. Ayer, of Lowell, and, in his capacity as an engineer, made plans of and sold for the estate all of its land in Somerville, amounting to seventy acres.

In 1895–1896 he made for the Metropolitan Park Commission the surveys and plans for the Mystic Valley Parkway, from Winchester Center to the Old Mystic Pumping Station at the western end of the city of Somerville, and performed for the same commission some work in the Middlesex Fells reservation.

From 1887 till his death he was constantly engaged as a consulting engineer and employed as an expert by railroads, municipalities, corporations and private individuals, and in the adjustment of damages and awards and the appraisement of real estate.

His activities covered a broad field, and his recommendations resulted in many public improvements. His was the first suggestion to extend the Mystic Valley Parkway from the pumping station near West Medford to the Old Powder House in Somerville, afterwards constructed by the city and called Powder House Boulevard.

As engineer to the Cambridge Electric Light Company, 1902–1904, he made a request to the Charles River Basin Commission that a lock 45 ft. wide, with a depth of 18 ft. at low water, be constructed through the new dam at Craigie's Bridge, instead of one of less dimensions, which was done.

He was deeply interested in the cross-town boulevard through the eastern part of Somerville to connect Middlesex Fells with the reservations south of Boston and, as chairman of a committee of the Somerville Board of Trade, appeared many times before the legislative committee at the State House in advocation of it and succeeded in having a bill passed, which was vetoed by the governor for economic reasons.

Mr. Elliot was one of the founders of the Somerville Historical Society, of which he was president for three years. He took great pleasure in collecting ancient maps and manuscripts

relating to American history and particularly to that of Somerville, upon which latter probably no person was better informed. He prepared a brief history of the town and city in 1896.

Though we have a number of articles from his pen relating to engineering, most of which were printed in the Somerville *Journal*, he wrote largely on historical subjects. His writings show complete knowledge of his subject and are altogether interesting. His keen sense of humor appears frequently in his writings, as in his speeches and conversation.

His last appearance before the Somerville Historical Society was on November 24, 1908, on which occasion he read a paper on Charles Tufts, the founder of Tufts College.

Mr. Elliot became a member of the Boston Society of Civil Engineers, December 17, 1902. He was also a member of the American Society of Civil Engineers from August 7, 1872, to January 4, 1898; The National Geographic Society; Massachusetts Real Estate Exchange; Somerville Board of Trade, in which he took a very active part, and to which he devoted a great deal of his valuable time. He was a member of the Men's Club of the First Universalist Church; the Winter Hill Improvement Association; the American Historical Association; New England Historic-Genealogical Society; Sons of the American Revolution; and Delft Haven Colony of the Pilgrim Fathers.

Charles Darwin Elliot and Emily Jane, adopted daughter of Judge Nathaniel F. Hyer, were married in New Orleans, La., September 3, 1863, and five children were born of the marriage.

Mr. Elliot was very ill during the winter of 1907–1908. It was thought he had fully recovered from this attack, though his friends noticed a slight diminution of his accustomed vigor. His condition during the evening of November 24, while reading the paper on Charles Tufts before the Somerville Historical Society, caused great anxiety to his family and friends. He was much improved, however, on the following day and went about his duties as usual.

On Saturday, December 5, Mr. Elliot spent the entire day out of doors. He was chilled by the exposure and obliged to see his physician upon returning home, but was about the house on Sunday. During the evening he was taken seriously ill and for a time it was thought he would not survive and, though he rallied from this attack and was in his usual cheerful frame of mind the following day, the possibility of his recovery was slight. He did not leave his bed. There was another crisis on Wednesday and the end came most peacefully the following

morning. He died at 11 A.M., December 10, 1908. His death was due to heart trouble and other complications.

Services were held at his late residence, 59 Oxford Street, Somerville, on Sunday, December 13, and at the Winter Hill Universalist Church. The burial was at Woodlawn.

Rev. Francis A. Gray, the pastor, in his eulogy, paid tribute to the many-sided life of the deceased, whose first interest was to his family, where he displayed the spirit of loving kindness as husband and father. "Mr. Elliot next gave himself as largely as he could to the community. In his work of painstaking research into the traditions of the past, he sought to set in order those things which make for the betterment of American life. Absolutely honorable in all his dealings, he had a wonderful magnanimity of nature and was wont to see the best in every one he approached. A genial and gracious friend, he was continually giving to others without stint and measure."

George A. Kimball,
J. Albert Holmes,
Charles A. Pearson,
Committee.

Editors reprinting articles from this Journal are requested to credit the author, the Journal of the Association, and the Society before which such articles were read.

Association of Engineering Societies.

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THE RELATION OF THE STEAM TURBINE TO MODERN CENTRAL STATION PRACTICE.

By G. R. Parker.

[Read before the Joint Meeting of the St. Louis Branch of the American Society of Mechanical Engineers and the Engineers' Club of St. Louis, December 11, 1909.]

Since the commercial introduction of the steam turbine into this country some seven years ago, so much has been said and written on the subject that it seems almost superfluous to attempt to add anything to the already large store of general information.

A review of steam turbine principles will, therefore, be to many of you merely a repetition of ground covered many times, but in any branch of science an occasional brief return to basic principles is never out of place.

The objective of designers of all classes of steam prime movers has been the same, namely, the conversion of the heat of combustion into mechanical or electrical energy. And the medium employed has been water. It is true that the over-all efficiency of our best steam prime movers is regrettably low, due to the fact that so much heat has to be given to water before any of it can be converted into mechanical work. For example, the total heat per pound of steam at 150 lb. gage pressure is about 1195 B.t.u. If this be expanded to a 28-in. vacuum, the total energy available in this expansion range is only about 321 B.t.u. This 321 B.t.u. is all of the total heat we are able to use, and, in

practice, commercial machines may convert anywhere from one half to three fourths of this available energy into mechanical work.

That the steam turbine was delayed for so many years after its inception in early historic times was due to two principal causes. First, the construction of turbine blades and other necessary elements required tools and machines of greater refinement than any formerly available; and second, the high speed of the turbine rendered it impossible to utilize its power until the perfection of the electric generator. It remained for such eminent inventors as the Hon. C. A. Parsons, of England, and Mr. C. G. Curtis, of this country, to perfect a commercial machine. It is only fair to mention also the names of De Laval, Zolley, Ratteau and others whose work has contributed much to the present perfection of the steam turbine.

We are in this country interested chiefly in the Parsons and Curtis types. Briefly, the Parsons principle involves the continuous expansion of steam through alternate rows of moving and stationary blades, the former being attached to the spindle and revolving it, and the latter redirecting the steam against other revolving blades. The expansion of the steam thus occurs in both moving and stationary blades, and motion is given the rotating element both by the impact of steam on the moving blades and its reaction on leaving them. The machine is ordinarily called a reaction turbine and may, in a general way, be compared with a reaction water wheel.

The Curtis principle differs from the Parsons in that the expansion, instead of being continuous throughout the machine, is broken up into a series of pressure steps or stages. Each one of these contains a row of stationary nozzles which expand the steam through a certain range and direct it with large velocity against the moving buckets, through which it passes with practically no further expansion, thus moving the revolving buckets by impulse only. The expansion of steam, therefore, occurs only in the stationary element. This type of turbine is referred to as the impulse type and is somewhat analogous to the impulse water wheel. It is with the impulse turbine as invented by Curtis and perfected by Emmet that this present paper deals.

The problem confronting all turbine designers has been to reduce the speed to such an extent that the turbine itself and the generator connected with it could be made to withstand safely the large centrifugal strains. Other speed limits are imposed by the commercial electric frequencies in use in this country. Evi-

dently, 1500 rev. per min. is the highest speed for a 25-cycle generator and 3600 rev. per min. for 60 cycles.

The most efficient speed for any single impulse wheel driven by a moving liquid or gas is one half that of the moving element. Steam exhausting from a pressure of 150 lb. gage through a suitable nozzle attains a velocity about 4000 ft. per second. Half this speed, or 2000 ft. per second, should, therefore, be the correct peripheral speed of a single impulse wheel placed in the path of the steam jet. Evidently such a peripheral velocity would necessitate an angular velocity far in excess of the highest commercial speeds. To reduce this high angular velocity, and at the same time retain the efficiency of his machine, Curtis made use of two expedients. The first consisted of utilizing the velocity of a single expansion in more than one wheel, and thus divided the initial velocity into two or more parts. This reduced the peripheral speed of each wheel in inverse proportion to the number of wheels. However, there are practical limits to the number of wheels which can be utilized in a single expansion; therefore, to still further reduce the speed, Curtis not only divided the velocity of a single expansion into two or more steps, but divided the total expansion range into two or more separate expansions. Or, expressing it another way, he put several turbines, each one of which contained two or more wheels, in series, the steam passing successively from one to the next, and each one absorbing its proportion of the steam energy.

A considerable amount of experimenting was done in the early days of manufacture to determine the correct number of stages, and wheels per stage. Thus the first large turbines built contained two stages and three rows of revolving buckets per stage. Later investigations showed that for all large turbines the most economical results were obtained with not more than two rows of buckets per stage, and this is the present standard. With the exception of very large machines, four stages has been regarded as the correct number, although recent experiments indicate that possibly greater economy may be obtained with one or more additional stages.

One of the principal and most justly founded claims for the steam turbine is its relatively high economy at other loads than rated load. Even in the best designed reciprocating engines the best economy is obtained at one point, and at loads greater or less than this, cut-off occurs either too early or too late for the cylinder proportions, and the result is a steam consumption per horse-power relatively higher at these loads Since very few

power loads can be made to hold constant at any given point, the average economy on a varying load may be considerably in excess of the best obtainable value.

On the other hand, the Curtis principle permits high economy at all loads. This is due largely to the method of governing. Most impulse wheels have partial peripheral admission of steam, i. e., steam flowing through only a portion of the wheel at one time. Thus in the Curtis type the nozzles expanding the steam and admitting it to the first-stage wheel extend over only a small portion of the wheel periphery. These nozzles are generally placed close together in a single continuous arc, although in the very large sizes two groups of nozzles spaced 180 degrees apart are employed. The admission of steam to these nozzles is controlled by a corresponding series of valves, which vary in number according to the size of the machine. The opening or closing of these valves evidently permits the passage of steam through a greater or less number of the nozzles. The steam emerging from two or more nozzles combines to form a continuous belt or stream of steam of constant width, determined by the width of the nozzles, and of length corresponding to the number of nozzles open. Governing is thus accomplished by automatically varying the length of this steam belt by the successive opening or closing of the admission nozzles. The steam thus arrives at the point of inlet at full pressure, regardless of the load, and whether one or all the nozzles are open, it is expanded with practically no throttling. The result is evident in the steam consumption curves. At fractional loads, the steam consumption is relatively good, and as the load is increased the economy continues to improve, the load-water rate curve gradually becoming a nearly straight line. With such a machine it is possible to operate over at least half the range of the machine with maximum and minimum economy not varying over 5 per cent. from the average. The advantages of this feature on a fluctuating load are obvious.

The question is often asked as to what are the most economical steam conditions; i. e., initial pressure, vacuum and superheat. While there is much discussion on these points, the present American practice is becoming reasonably standardized. As to vacuum, there is no question that it is worth while getting the highest obtainable. Twenty-eight-inch, or, more properly speaking, 2-in. absolute and even higher, vacuum can readily be obtained with modern condensing apparatus. Steam pressures vary from 150-lb. gage to 250-lb. gage. In the smaller and

medium-sized plants probably 150 lb. to 175 lb. is about right, while in the larger ones 175 lb. to 250 lb. should be employed.

The arguments for and against superheat are numerous, but the consensus of opinion is inclined to favor a reasonable degree of superheat, at least in the large and medium-sized plants. Superheat ranging from 50 degrees fahr. to 200 degrees fahr. is in common use. Regarding high pressure and high superheat, it should be borne in mind that the percentage increase of available energy given the steam is much greater than the percentage increase in fuel necessary to produce these conditions.

Modern steam turbine practice has advanced so rapidly in the past few years that quite startling changes have been effected in some of the original turbine stations. Improvements in details of construction, and increase in speed, have greatly reduced the size and weight per kilowatt. About six years ago the first large turbines were installed in the new Fisk Street Station of the Chicago Edison Company. The first three machines were vertical two-stage machines of 5000 kw. capacity, and the fourth, installed somewhat later, was of the same capacity but of the five-stage type. Within the last year these four machines have been removed and replaced by four vertical machines of 12 000 kw. continuous capacity each. These occupy no greater space than the original machines, and no increase in the capacity of boilers supplying them was necessary. The Fisk Street Station now contains altogether ten similar machines of 12 000 kw. each. The Quarry Street Station of this same company at present contains three vertical machines of 14 000 kw. each, and three more will be installed during the coming summer. The economies obtained in these plants are reflected in the rates the Commonwealth Edison Company is able to make its consumers.

A somewhat similar evolution is now under way here in St. Louis. In 1905 the present Union Electric Light and Power Company installed two 5000 kw., 500 rev. per min., 25-cycle, 6600-volt vertical turbines. Later, two more 5000 kw. machines were added, but with 60-cycle, 2300–4000-volt generators. The present plan, which is now well under way, is to replace all four machines with other turbines of 12 000 kw. capacity each.

The natural question is, Can it possibly be a business proposition to throw out four large turbines which have been in use only three or four years? That the answer was affirmative was due to three principal considerations.

(1) The larger machines could be installed without increase in floor space.

(2) The improvement in economy represented an annual charge which if capitalized would more than pay for the additional investment.

(3) Practically no new auxiliary apparatus or station piping would be required.

That these considerations were based on correct assumptions has been amply demonstrated. The first 12 000 kw. turbine has now been in commercial operation for several weeks.

In making this installation, not only was it possible to utilize the original foundations, but even the base of the old turbine, which also constitutes the exhaust chamber, and the step bearing support was utilized in building the larger machine. It was, therefore, not necessary to remove this base from the concrete, or break the connection to the condenser. In a general way it may be said that the old 5000 kw. turbine was lifted bodily from its exhaust base and a 12 000 kw. machine installed in its place without disturbing the condenser piping and auxiliaries. The increase in capacity means that in this portion of the station the kilowatts per square foot of station has been more than doubled. Even the original four 5000 kw. machines were placed unusually close together, and when the remaining three are replaced by larger machines it seems probable that the turbine portion of the Union Electric Light and Power Company station will show a greater kilowatt per square foot than any other station in this country.

Aside from the increase in capacity, the improvement in steam economy is very large. Unfortunately, detailed test figures are not available at this time, but it is probable that the new turbine will show an improvement of at least 20 per cent. over the one which it replaced, besides having a flatter load curve. On this basis considerations of economy alone would have warranted the change. In addition, this enormous increase in power has been effected without any considerable change in the existing piping and auxiliary arrangements.

Any steam turbine operating condensing with the usual pressure and vacuum derives roughly half of its power from the expansion of steam from boiler pressure to atmosphere, and the other half from the remaining expansion from atmosphere to vacuum. Thus in a four-stage machine, atmospheric pressure is reached between the second and third stages. A reciprocating engine operating under similar conditions would not derive its energy from the steam in this proportion. The average engine actually develops some 15 or 20 per cent. of its power from the expansion of steam below atmosphere.

A consideration of these facts brings us to the low-pressure turbine. In a general way, it may be stated that a low-pressure turbine is that part of the high-pressure turbine which normally operates below the atmospheric line. In general, it is possible to build a low-pressure turbine for compounding with a non-condensing engine with the expectation of approximately doubling the capacity and halving the steam consumption, while the same thing may be done with a condensing engine to a less extent. Most condensing engines can be operated at their full capacity, non-condensing, with a slight adjustment of the valve gear. The increase in steam consumption of the engine alone with this arrangement will be between 15 and 25 per cent., but the low-pressure turbine adds 90 per cent. to 100 per cent. capacity, so that the net economy effected is worth going after regardless of the tremendous increase in capacity. Installations of this character were first made in this country four or five years ago, although greater interest has been stimulated during the last year or two. One of the early installations was in the plant of the East St. Louis and Suburban Railway Company, where an 800 kw. and a 1000 kw. low-pressure turbine were installed in connection with non-condensing engines. The most notable installation is that recently made in the power house of the Interboro Rapid Transit Company in New York City. This station consists of the highest type of reciprocating engines, operating under the best possible engine conditions, and develops an economy comparable with the best engine stations in the country. It has, however, been possible to install in connection with one of these engines a low-pressure turbine with a nominal rating of 5000 kw. It is probable that a detailed report of this installation will be published at an early date. For the present it is sufficient to say that the improvement in steam consumption of the combined engine and turbine has effected a saving in coal consumption of over 20 per cent., and the combined capacity has been more than doubled. The turbine generator is of the induction type and runs permanently in parallel with the engine generator. With this arrangement it is unnecessary to provide any speed governor on the turbine. The engine governor takes care of both machines. It is interesting to know that in spite of the size and special character of this installation, the machine was started and placed in commercial service without a hitch of any kind. A second machine of similar characteristics but with a larger generator is now being installed in connection with the second engine, and the present plan contemplates one turbine for each engine throughout

the station. When complete the station capacity will have been more than doubled without any increase in real estate or building investment.

What has been done in this connection can be accomplished on a smaller scale in almost any plant of 300 kw. or larger operating reciprocating engines, either condensing or non-condensing, providing proper condensing facilities are available.

A valuable feature in connection with the Curtis low-pressure turbine is that, owing to the fact that even with low-pressure steam the primary admission nozzles only extend a portion of the way around the wheel circumference, it is possible to equip any low-pressure machine with another set of nozzles primarily designed to expand steam from boiler pressure instead of from atmospheric pressure. A machine so equipped can be operated either as a strictly low-pressure machine, or, should the supply of exhaust steam fail entirely, due to shut down of the engine or for other reason, it can operate and carry its full capacity on boiler pressure steam alone, or it can be operated on a mixture of the two, in case the load exceeds the supply of exhaust steam. It should be remembered that these high-pressure nozzles do not throttle the steam to a lower pressure, but are actually designed to economically expand it to the proper internal pressure of the turbine. Such a machine, operating on high-pressure steam only, will show an economy fairly comparable with an engine or turbine regularly designed for high-pressure operation. The operation of these high-pressure nozzles is automatically controlled by the main governor, and in practice it has been found possible to instantly cut off the low-pressure steam supply without a noticeable variation in the speed of the turbine. This evidently makes a most flexible machine and one that accomplishes two most desirable results at comparatively small cost, namely, increase in capacity and decrease in steam consumption.

It is perhaps worth while mentioning, also, the enormous field which has been opened up by the strictly small turbine; that is, from 300 kw. down. These machines for the most part are designed to operate non-condensing, and the argument in their favor is that they are an extremely simple machine requiring practically no attention or adjustment. The best proof of their extremely rugged construction is found in the fact that out of 500 small turbines of 25 and 35 kw. capacity now operating in various parts of the country a large percentage are in use by the various railroads for electric train lighting, under which condition it is hardly necessary to say that they receive a minimum atten-

dance with very few opportunities for the making of repairs. The confidence which the railroad companies place in these sets is evident from the fact that many of the more modern Pullman cars are equipped with electric fixtures only, no provision being made for gas light. Machines of this size and larger are also in general use as exciters for large alternators. Numerous cases are on record where such machines have run continuously for periods of three or four months or more without at any time shutting down.

In conclusion it may be said that the Curtis turbine has been built and placed in successful operation in sizes from 5 kw. to 14 000 kw., and at the present time even larger machines are under consideration.

DISCUSSION.

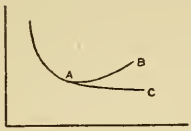
Mr. Parker. — Since writing this address, I have learned from Mr. Hunter that the actual figures were 15.5 lb. steam per kw-hr., the turbine not yet having its full load or vacuum.

I want to say one word more: nearly all speakers on the performance of steam turbines refer, at some time or another, to the famous Fisk Street Station of the Commonwealth Edison Company in Chicago, but I want to say that this station is vastly more an ideal one and the problems to be met with are not nearly as severe as here in St. Louis, and the results which are obtained under the tremendous difficulties surpass some of those in these other stations.

The Chairman. — We are very much indebted to Mr. Parker for this interesting address. Perhaps in no branch of steam engineering has the progress been so great in recent years as in steam turbine work. A discussion of this question, gentlemen, is now open. I trust it will be a very active discussion, and we shall be glad to hear from any gentleman present. Mr. Parker, I would like to ask about the overload capacity of standard turbines, — do they carry as much overload as the ordinary reciprocating engine?

Mr. Parker. — Well, that is a very interesting point, Mr. Bryan. Formerly, steam turbines were designed to follow the practice with regard to reciprocating engines; that is, they were given a temporary overload capacity for a period of 2 hours, more or less, in excess of their normal rating. Since then, machines are rated on what is called a maximum basis. It is a misleading term. A better term would be continuous basis. That is, the proportions of the steam unit, so-called, and the generating unit,

are more nearly alike. The reasons leading to this change I think I can explain, perhaps, here on the blackboard.



Let the figure represent the typical engine curve, in which the point of maximum economy is at "*A*."

Evidently, the capacity of the engine has by no means been reached at that point, because a further admission of steam brings it to "*B*." With such a type of engine it may be desirable to put on a generator which may utilize that power for limited periods of time. But the turbine in coming down to and reaching the full load point — it actually goes beyond that — goes on a straight line, and additional load really improves the economy. Now, the natural thought that occurred to the turbine designers was, Why rate a generator at that point "*A*" when by this means you increase the required capacity of the turbine 50 per cent., which can be used, so to speak, for only a brief period of time, say only 2 hours of the twenty-four? So it was decided to put on a generator rated at that point "*C*," keeping the temporary overload also at this point rather than put on a generator rated there with 50 per cent. overload.

Supposing the size of the turbine was 1000 kw., and it was decided to put on a 1500 kw. generator. Now, let's see what the advantages are. The first case will be that of the load which operates somewhere near this point "*A*," of course giving a little range, such as we may find in some industrial and perhaps a few lighting plants. Other lighting plants, on the contrary, will have a load swinging over a considerable portion of this curve. Now, the argument is often raised that on such load the engine with overload is more desirable, but a close inspection of the curve will show that it is an erroneous impression. If this machine has a fluctuating load, you will have a certain range of load over which it is possible to operate, say from about a load to a load and a quarter, somewhere back here. Now the generator is big enough to take care of the continuous capacity of the machine — you are able to actually go considerably beyond it — and it is operating over a portion of the turbine curve which is very flat, and the average value over this portion of the curve "*A*" to "*C*" will be much lower than over this portion "*A*" to *B*," so that in general it is now thought desirable to employ turbines with generators capable of developing their full capacity continuously. Of course that doesn't mean that either the generator or turbine is going to fall down at that point. In practice, the

machine on the so-called maximum rating will carry almost as much overload as the machine on the overload basis, but you have got to draw the line somewhere, and nowadays turbines are given a fixed rating which is supposed to be the maximum they will carry.

THE CHAIRMAN. — It might be interesting, Mr. Parker, to compare the space occupied by both the modern and the older types of turbines with that of reciprocating engines — as, for instance, those we saw to-day. Can you give us some approximate figures?

MR. PARKER. — I have no definite figures in mind. Most of you saw to-day, at Ashley Street, a 3000 kw. unit, which must occupy a space somewhere between five and ten times as much as the 12 000 kw. turbine. The turbine is four times as big, but it takes up one fifth of the floor space. You may apply the same reasoning to height, although in most stations that is the least important factor.

THE CHAIRMAN. — Could not the height of the Ashley Street station have been cut down 20 or 30 ft. for turbines?

MR. PARKER. — It could have been, but I do not know that it would be specially desirable. More room in the station is better, although increase of height doesn't matter. The addition of a few vertical stone or brick is rather a desirable feature. It is interesting to know that the Waterside Station of the New York Edison Company was laid out originally with sufficient height so that if the turbines proved to be a failure, as many believed they would, reciprocating engines could be installed. It is interesting to note that this has not been done.

THE CHAIRMAN. — One other question, Mr. Parker; I think you made a statement, referring to the Chicago plant, that the new turbines, which were of 12 000 kw. capacity as compared with five, required no additional boiler capacity.

MR. PARKER. — Yes, that is true.

THE CHAIRMAN. — Well, certainly, the new water rate is more than one half the old rate?

MR. PARKER. — Well, it did not come very far from it. I do not know that I can work it out accurately, but let us see. The first machine took about 23 lb. steam per kw-hr.; and the new ones take about 13, so that the total increase has not been so very tremendous; thus,

$$5\ 000 \text{ by } 23 = 115\ 000$$
$$12\ 000 \text{ by } 13 = 156\ 000$$

In order that you may not get a wrong impression of the

plant you have here, the figure of 13 lb. attained in Chicago is with a very high vacuum, a very high degree of superheat and also high steam pressure. These turbines are identical with those at Ashley Street, and, operating under the same conditions, the latter would show the same economy.

THE CHAIRMAN. — I believe that there are 55 or 60 degrees superheat at Ashley Street Station?

MR. PARKER. — Yes.

PROF. H. WADE HIBBARD. — I have thought of a graphic comparison of floor space in the comparison of a horizontal reciprocating engine and a Curtis steam turbine. The floor space occupied by the former would be about the space of my four fingers, and the space occupied by the Curtis steam turbine a little larger than my thumb nail.

Mr. Chairman, I thought that possibly for those who might not be as familiar with steam turbine work as with other lines, some further comparisons might be of interest, for example, the velocity of the fluid used. On the Pacific Coast, in hydraulic turbine work, they deal with a velocity of water of some 300 ft. per second. Now, if you only had 50 lb. boiler pressure and used a suitable expansion nozzle and exhausted it into the air, you would get a velocity of steam identical with the velocity of the bullet from the new United States Springfield army rifle — the new high-power repeating rifle — 2300 ft. per second. That is only 50 lb. boiler pressure, and, as the speaker has said, we are running up to 4000 ft. per second and more in single wheel impulse turbines.

We ought not to carry away a wrong idea of the meaning between impulse and reaction, because, as I understand, in the steam turbine of the Curtis or other impulse type, they use the reaction principle; better terms have been devised by our German friends, which, being translated, are that the impulse turbine has an "equal pressure" and the reaction turbine an "unequal pressure." If you put pressure gages at certain places in the impulse turbine, so-called, the pressure is the same on both sides, whereas with the reaction type it is different. Or, as the speaker said, the impulse turbine gets the steam to the desired velocity in the fixed nozzles, and then discharges it down upon the curved vein or bucket, and the steam does not increase in its velocity as it passes through the moving bucket; but in the reaction turbine the expansion of steam takes place in the curved moving bucket as well as in the fixed nozzles. The impulse turbine certainly uses the reaction effect in chang-

ing the direction of the flow of steam as it passes through the moving vein.

The economy of the steam turbine *vs.* the reciprocating engine has appeared to be about the same in capacities from say 400 to 2000 kw. With regard to the Ashley Street Station, the figures that have been given to-night for the reciprocating engines are, I believe, $16\frac{3}{4}$ lb. of steam per kilowatt hour, and for the smaller turbines that are being taken out, 21, whereas, the new modernized turbine is giving $15\frac{1}{2}$.

It should be recognized also by those who may have seen figures that looked discordant, that kilowatt hour and brake horse-power hour are two different things; for example, the $16\frac{3}{4}$ lb. of steam per kilowatt hour is the same as $12\frac{1}{2}$ lb. of steam per brake horse-power hour, so that the figures of the new 12 000 kw. turbine that we have seen this afternoon, of $15\frac{1}{2}$ lb. of steam per kilowatt hour, mean about $11\frac{1}{2}$ lb. per brake horse-power hour. For any capacity of steam turbines, say from 3000 to 9000 kw., a list of tests that I have been recently examining shows that you ought to expect about 12 lb. of steam per brake horse-power hour from the turbine, and from reciprocating engines of the same capacity 13 lb. of steam per brake horse-power hour. Concerning what the speaker has said regarding the field for the small capacity steam turbine, these facts may be of interest:

In the small reciprocating engines, from 100 to 200 h.p., there is a great deterioration in economy due to the leakage of valves that have been running a little while, and other causes, so that you are liable to get in a small reciprocating engine, say one of 200 h.p., a steam consumption of perhaps 49 to 60 lb. of steam per kilowatt hour, whereas, in the small capacity steam turbine, some recent figures are:

100 kw. turbine	25 lb.
200 kw. turbine	22 lb.
500 kw. turbine	20 lb.

and the deterioration is very slight, so that after, say, five years of service, you will get a deterioration of about 2 per cent. in steam economy, showing that the steam turbine is a better old machine than the small reciprocating engine. I remember a saying by Professor Sweet many years ago, when he was professor at Cornell, that almost anybody can design a good new machine, but it takes an angel to design a good old machine, — and I think we should congratulate our steam turbine friends. If they can make in three or four years such changes as from 20 lb. down to $15\frac{1}{2}$ lb., then there is no knowing what they will

do for us if they refrain from putting on angels' wings for a few years longer.

As to costs, I have some figures here of a 750 kw. steam turbine and its auxiliary machinery, foundation, etc., as compared to a corresponding reciprocating engine in the same service. The steam turbine cost $37 per kilowatt, the reciprocating engine $40 per kilowatt. In a larger capacity, 1500 kw., the steam turbine shows up at $30 per kilowatt, and the reciprocating engine at $40 per kilowatt. A large manufacturer of both large reciprocating engines and large steam turbines states that in a very large power station we may expect reciprocating engines to cost us from 35 to 60 per cent. more than steam turbines. This machine that you have seen to-day is not a large machine. I understand that a machine of 24 000 kw. has been built for Krupps in Germany. I notice in the paper of the speaker that larger machines than the 12 000 kw. are expected to be constructed.

As to the amount of vacuum, the speaker uses these words:

"There is no question but that it is worth while getting the highest vacuum obtainable."

I presume he might want to tell us further what he means by that word "obtainable," because there is no question but that there are conditions where it is unwise to strive after extreme vacuum. I have some comparative figures here of a 2000 kw. unit, in which the condensing machinery for a 28-in. vacuum would cost about $4000 more than for a 26-in. vacuum. Putting that into figures of savings, and taking 15 degrees fahr. difference in temperature between the temperature of the condensed steam and the discharged water, taking a fair rate of 60 lb. of cooling water to 1 lb. of steam, and 60 degrees temperature of intake water, your maximum vacuum would be about 28.6 in.; with 70 degrees of intake water it would be 27.7 in. This is at sea level. If you have a station to be built at 1000 ft. above sea level, with that machine you will get about 1 in. less vacuum than down at sea level. So that it would seem that some of the conditions which indicate a very high vacuum — say 28½ or 29 in. vacuum — would be, at sea level, very cold water, a large quantity, very costly coal and a high load factor.

With a 10-hr. load out of the 24, and coal at $1.13, the saving due to a 28-in. vacuum as compared to a 26-in. vacuum was only 4 per cent. on the investment of $4000 required to get the 28-in. so small as to be practically negligible.

Mr. Parker. — Was that an engine or a turbine, Professor?

Professor Hibbard. — I believe that it was a turbine, but I am not sure.

Mr. Parker. — Four per cent. would be a small saving. I should expect to get at least 6 per cent. over the high ranges of vacuum.

Professor Hibbard. — That is about right. That is, of course, running for 24 hours. That would not justify an increase very much over the 26 in.

The speaker made no mention of the use of an accumulator for enabling one to run a steam turbine from a reciprocating engine that may be stopping off a little while and starting up again — as, for instance, a rolling mill engine. This is a somewhat recent application of the steam turbine in which the exhaust from the reciprocating engine goes into a large chamber of water, and the water acts as a sort of fly wheel of steam, so that when the reciprocating engine is stopped suddenly for half a minute or a minute — I think even 2 min. — the low-pressure steam turbine draws this steam from the hot water and thus does not have to stop. Another possible use for the low-pressure steam turbine might be in connection with a gas-engine plant, namely, to use the jacket cooling water from the gas engine cylinder and run a low-pressure steam turbine from that water. Low-pressure steam turbines have been run from steam pressure as low as 5 or 6 lb. below atmospheric pressure, and apparently run successfully.

In marine practice, Mr. Parsons has never advised an all-turbine equipment. For ships running under 15 knots, the slower tramp steamers, for instance, he advised a combination. For example, here is an engine for a ship running $11\frac{1}{2}$ knots per hour with the reciprocating portion of the machinery exhausting at 7 lb. absolute, and the steam consumption is estimated to be from 15 to 20 per cent. less than if an all-turbine plant had been installed in the place of the ordinary triple expansion reciprocating engine.

As to the degree of superheat: the superheating of steam for a reciprocating engine makes a saving largely because of the reduction of steam condensation. The saving due to the use of superheat for steam turbines appears to reside in the increased mobility of the steam. It is not so much like molasses, but more like alcohol, and thus reduces the friction upon the steam turbine blades; and naturally we should expect, which I think has been often borne out by test, that the very large number of blades in the Parsons steam turbine show a greater economy

resulting from the high degree of superheat than the small number of blades in the Curtis steam turbine. Naturally, the saving by that more mobile fluid flowing through the larger number of blades would be a greater total saving than that going through the small number of blades.

Mr. Day. — Mr. Chairman, I would like to ask Mr. Parker how he accounts for the increased steam economy on the recent large units, as compared with the 5000 kw.

Mr. Parker. — It is perhaps a difficult question, and it is impossible to assign any one reason for it. There are several. The machines in the Union Electric Light and Power Company's plant are of a variety of types. Mr. Hunter remarked yesterday that he thought he had landmarks of the entire steam turbine variation, and he very nearly has. He has the two-stage 500, taking about 25 lb. of steam; a four-stage 2000, taking about 23 lb. of steam, and two types of 5000, one of four-stage and one of five-stage, differing perhaps a point or two, and, last of all, his most recent machine, taking 15½ lb. Now, the reasons for the gradual variation are perhaps primarily due to the improvements in buckets. Our theory and practice have been brought closer together, and we have designed buckets which are both practical and theoretical, and we have gone through a great number of steps; that is, subdivided the expansion of steam into a greater number of stages, and we have gained a higher speed, and the last named is perhaps the most important feature, because that means that the speed of the revolving buckets is greater than that of the impinging steam; therefore we are theoretically ahead of our practice. The general improvement in bucket design may account for our increased economy. In this connection we think that during the next five or six years we shall get to better figures than this, although I cannot hold out very much hope for it to-day. We are approaching the theoretical limit. This machine at Ashley Street has an economy, theoretical economy, I should say, over all efficiency, of probably somewhere around 68 per cent.

Mr. Bryan. — That is thermal efficiency?

Mr. Parker. — Yes. I think it would not be very far from that. We may get that up as high as 75 per cent. in time, but there are limits beyond which we cannot go. There are certain constant losses in any machine, constant losses in radiation, losses in wheels revolving in atmospheres of different densities, and the friction of the steam itself passing over blades, and losses due to the fact that the steam does not impinge upon the blades

in the same plane as the blades. That is, you have got to have a certain amount of angle for the steam in striking the bucket; now there will always be a loss corresponding to the ratio of the hypothenuse of the triangle to the horizontal, so that you may always expect losses of that character. I should be surprised if you got them much above 75 per cent., although it is impossible to predict what the future will bring forth. There are one or two points I would like to comment on, made by Professor Hibbard. One of them is the conversion of pounds per kilowatt hour to pounds per horse-power hour. A very difficult transmutation, I may say, when you are comparing the small reciprocating engine with the small steam turbine, if you do not take into consideration the losses of both the engine and the auxiliary generator. The friction losses of an engine in ordinary commercial service run as high as 10 per cent., and the small generator will seldom run above 90 per cent. efficiency, so that after you divide by the ratio of kilowatt to horse-power, you have still got something like 15 per cent. to 20 per cent. in favor of the turbine beyond that point.

Mr. Bryan. — The engine rating usually being per indicated horse-power?

Mr. Parker. — Yes. But brake horse-power would take into consideration the engine losses. Another feature may be one that I have already referred to, namely, the fluid-like characteristics of the machine. In most stations it is very hard to hold a constant load.

Mr. Bryan. — Do I understand you to say that the water rate continues to fall, though very slowly, with all increases of load?

Mr. Parker. — That would depend a good deal on the individual machine. It may be said of almost any Curtis turbine at and beyond rated load with the full vacuum constant.

Mr. Bryan. — It never begins to increase again?

Mr. Parker. — Under ordinary conditions, no. There may be some exceptions, but generally that is a fair statement. Taking a concrete example: the 12 000 kw. machine at Ashley Street was guaranteed at one-half load, 16.4 lb., and the same guaranty made at 12 000 kw., so that over a range of 50 per cent. the builders' guaranty would be exactly the same thing. As to the question of a vacuum, I should, perhaps, have modified that statement and said that a high vacuum is only applicable to a steam turbine. I question very much if a greater range can be developed in the ordinary reciprocating engine, especially in the

smaller sizes, beyond 4 in. absolute, for the reason, as you know, that at the higher vacuum the volume of steam becomes much larger than the low-pressure exhaust passages can take care of, and there is obviously no reason for trying to enlarge them. So probably with three engine cylinders, 26 in. is high enough. In the turbine, on the other hand, there is no question but what it is worth going after; that is particularly true in big machines. By big machines, I mean from 2000 kw. up. If it is possible to get 29 in., it is worth going after.

Mr. Bryan. — You would not say that irrespective of the cost of getting cooling water?

Mr. Parker. — No, I should not. I assume in both cases that there is ample cooling water available. With each additional inch of vacuum you get 275 000 ft.-lb. available energy, which represents an increase of about 10 per cent. Now, if you have an engine that will utilize any large proportion of that, it is desirable to go after it. In practice a turbine will develop some 60 per cent. of it. So you will get from 28 to 29 in., about 6 per cent. improvement in economy, and, of course, a corresponding increase in your capacity. Now, without going into any lengthy discussion of that, I think you will appreciate that it will be secured at almost no investment in additional apparatus, provided cooling water is available. It is only fair to modify that and say that in most plants of 1500 to 3000 kw., 28 in. is high enough. But in the very large ones, and where a very high vacuum can be obtained, it is certainly well worth while trying to get.

In regard to the steam regenerator, that is an invention of Professor Rateau, and unquestionably a very clever arrangement. As the professor said, it is to equalize the steam flow in case of a very intermittent supply of exhaust steam, and the experience of the manufacturers is that the high-pressure nozzles supplied with the high-pressure machine, which I explained in my paper, are a much simpler and equally effective device. That is, should the supply of exhaust steam fail, the high-pressure nozzles automatically open up and admit live steam, and while no tests are available to show the improvement of one over the other, I am inclined to think that even if the engine were shut down for two or three minutes, it would still be better to admit the high-pressure steam through the high-pressure nozzles. Any steam passing out under pressure will simply blow off into the atmosphere, so that the average of saving would not be very great. I think that probably the mixed pressure factor is better than the steam regenerator.

As to the possibilities of low-pressure turbines in connection with gas engines, it may also be said that the water from the cooling jacket and the exhaust gases may be led through suitably designed coils, and perhaps get a pressure somewhere around atmospheric, in which case the low-pressure turbines have a larger field in connection with gas engines.

THE CHAIRMAN. — Professor Ohle, have you anything to contribute to this discussion?

PROFESSOR OHLE. — What I have in mind is the consumption of steam by the steam turbine, which is practically constant over a large range of load, which we cannot expect to be the case with a steam engine. Then in the marine work that Professor Hibbard spoke of there are tests on record where there is shown a saving of over 50 per cent. on a cruiser. Under fourteen knots he said it would not pay, probably, to put in a turbine, but for anything over that you would have a saving, and as the speed went up the saving would increase. There it is necessary to have a little different type of turbine; you have to have larger rotating parts. Of course, in stationary practice, we have a high and low speed. There we have the larger rotating part and attempt to get a slow speed. As the speed of the vessels goes up, it is possible, however, to use a smaller turbine. Of course there has been some difficulty in reversing, and in some cases they have put in small turbines running in the other direction, so they could use it if necessary, and in others they have a reversing mechanism put in with the turbine; that is, it rotated with the exhaust pressure and then when high-pressure steam was put in it rotated in the proper direction; that is, it reversed and changed the direction of the ship.

MR. DAY. — Speaking of economies due to increased vacuum, isn't it a fact that, as far as the station and the plant efficiency are concerned, there is a limit to the vacuum on any unit, whether it be a reciprocating unit or a turbine, especially where the hot well discharge has a low temperature, and, therefore, a considerable amount of heat has to be added to the water as it enters the boiler. It seems to me there would be a point where a greater vacuum would not be desirable as far as plant economies are concerned.

THE CHAIRMAN. — Undoubtedly all the elements must be taken into consideration.

Mr. Day, can you give us any explanation of what it is proposed to do with the pumping engines at the water works? Have those plans developed far enough?

Mr. Day. — The plans have not developed sufficiently. But we have in mind one or two propositions. Either change the valve gear on the compound engines at the Chain of Rocks, so that the exhaust pressure from the high-pressure cylinder would be at atmosphere and run a low-pressure steam turbine in conjunction with the pumps. Then there is an alternative proposition, whereby we take the steam at the vacuum at which it is exhausted, which is generally around 9 lb. Sometimes it runs a little better, — that is, 6 lb. absolute pressure. We have propositions from some of the turbine builders guaranteeing steam consumption of 40 lb. with small units running in the neighborhood of 230 h.p.

The Chairman. — That is per indicated horse-power?

Mr. Day. — Indicated horse-power steam turbines.

Mr. Day. — But there is sufficient steam available from any two compound engines at the Chain of Rocks, which are rated at 30 000 000 gal. capacity, to operate a 21 000 000-gal. pump, even exhausting at 6 lb. absolute. We have guarantees of 40 lb. of steam per horse-power hour at 5 lb. absolute expanding down to within 1 in. of perfect vacuum.

Mr. Parker. — It might be interesting to have Mr. Hunter tell us the time that elapsed from starting to install this turbine to when it was first run.

Mr. Bryan. — What is that period, Mr. Hunter? I would like to get Mr. Hunter to offer a few remarks. Mr. Hunter is a very interesting conversationalist *tête-à-tête*. I think, if my figure is correct, it was six months? Isn't that correct?

Mr. Hunter. — Yes, sir; six months.

Mr. Parker. — From the time the contract was signed until it was placed under load. Mr. Hunter himself opened the throttle valve.

Mr. Smith. — I would like to ask something about this efficiency test; whether or not Mr. Stott in New York has made any tests at different vacuums, and if it varies the efficiency of the turbine when operating with the exhaust of reciprocating engines?

Mr. Parker. — So far as I know no efficiency tests have run over any considerable extent of vacuum, but it would be very easy to predict that the results would be disastrous if the vacuum were allowed to drop very much. From 26 in. down it is questionable whether it would even do to run a low-pressure turbine.

Mr. Smith. — You mean with smaller vacuum than 26 in.?

Mr. Parker. — Yes.

Mr. Smith. — I mean over 28 in.?

Mr. Parker. — Well, you might expect at that rating the same over-all economy that you might get in a high-pressure turbine; that would be an improvement, as I just remarked. About 6 per cent., roughly speaking, per inch of vacuum.

In connection with the question just raised as to what the proper initial pressure should be, Mr. Stott has made some tests in operating with a pressure higher and lower than atmospheric. He finds that over a very considerable range the economy is in no way impaired one way or the other. It appears that putting back pressure on the engine makes its efficiency worse, but improves the turbine to the same extent. A similar lowering of pressure makes the turbine worse, but improves the engine economy in the same proportion. So over a range of several pounds they just balance each other.

The Chairman. — Consider the ordinary non-condensing plant where the exhaust is used for heating. Isn't there quite a drop in efficiency where it is necessary to run on back pressures of 2, or 3, or 4, or 5 lb., for heating as compared with the free exhaust?

Mr. Parker. — In general the non-condensing turbine will take about twice as much steam as a condensing, and after you once start running a condensing turbine the difference of a few pounds would not make any tremendous variation. Of course it makes some. That raises an interesting point, though. The better way to operate a turbine on a new system is to bleed your steam from one of the intermediate stages, run the turbine with the condenser, and to tap it at that point in the inside of the rail where the pressure reaches about atmosphere; then tap the turbine and bleed the steam where the desired pressure may be 2 or 3 lb. An advantage of that is that whatever steam is not used passes through the remainder of the turbine and is condensed, and you get the full economy out of that, and whatever steam is necessary for heating is taken off after it has done some useful work in the first couple of stages.

The Chairman. — You cannot do that where your demand for heating requires the total capacity of the engine?

Mr. Parker. — No, that is true. In most cases, however, it is found that it is more economical to run it that way, because you have got exactly the amount of steam in both systems going through the heating system and through the condenser. But through the summer time you have full efficiency of the turbine.

The Chairman. — Of course that is not a question of great importance, because the modern heating systems are so devised as to require very little back pressure, if any.

Mr. Day. — I would like to ask Mr. Parker if this 12 000 unit will run non-condensing?

Mr. Parker. — I doubt very much if you can get 7000 kw. out of it.

[Note. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by May 15, 1910, for publication in a subsequent number of the Journal.]

ASPHALTIC OIL TREATMENT OF MACADAM ROADS.

By Charles H. Bartlett.

[Read before the Engineers' Society of Milwaukee, October 13, 1909.]

The matter of the building and maintenance of roadways is at the present time of more vital importance than ever. A few years ago the ordinary city street outside of the business section and the rural or country roads, could be paved with a macadam of limestone, trap rock or gravel material, and if honestly done and properly cared for the roadway would remain in good condition a length of time that well repaid the investment. But the automobile, the auto-truck and the auto-delivery wagon came, and these pavements began to disintegrate and wear away. The engineers and those in charge of roads began to look for methods of preservation. The roads were made heavier, the wearing surfaces were made of harder materials, more attention was given to the compacting or rolling of the roadways. More attention was given to the water sprinkling of them, and instead of soaking and flushing the streets a few times a day, the work was done oftener and less was applied at one time. And thus the life of a majority of the streets was brought up nearer to the old-time limit.

Those in charge of the building of roadways, be they engineers, commissioners of counties, cities or parks, or all of them together, are offered the choice of many kinds of pavements, but they are governed by several conditions.

1. The question of initial cost.

(*a*) This is governed by the availability of local materials.

(*b*) By the amount of work to be done.

2. The question of traffic to which the roadway is subject.

(*a*) A business street, a suburban street, and a park drive. Each has a class of vehicles passing over it that is different from the others.

3. The question of cost of maintenance.

4. The question of the life of the pavement.

(*a*) This question enters into all of the others.

1. As to cost: In our territory the following pavements are used and the prices given are average prices:

1. Limestone macadam		$0.80
2. Granite-top macadam		1.10
3. Brick	2 course on sand	1.75
	1 course on concrete base	1.90
4. Asphalt		2.20
5. Bitulithic		2.25

There are other kinds of pavements, but I will omit them as being of special kinds for special conditions.

2. The question of traffic is one that is easily observed by every one, and it is only necessary to remark in passing that the heavy traffic of the ordinary business street would quickly destroy the pavement that is perfectly good for the residence street or the park driveway. Yet the road builder must never lose sight of the fact that the lightest pavements must be so constructed as to be prepared for occasional heavy traffic.

3. The question of maintenance is the one on which all road builders differ. The advocates of each kind will tell you, and prove to you by his figures, that his favorite is easiest to repair and to keep up to standard. But beyond question macadam pavement of either kind is cheaper to repair than brick, asphalt and bitulithic in the order named.

4. The question of the life of the pavement is the great question, and enters into all the others and must be worked out by those in charge of the building and the maintenance.

Generally speaking, a macadam pavement is the cheapest to build because of the availability of the materials for its construction. Under ordinary circumstances it is the best roadway for suburban residence or park purposes. It can be built so as to be smooth, practically noiseless and, if properly rolled or compacted and drained, dustless and mudless. It is a fact that in most localities the majority of the streets are paved with some sort of a macadam, either of limestone, granite or gravel, and this brings us to the oil treatment of roadways.

In one of my expeditions after work in our line, I met a commissioner of public works who said to me after I had begun on the merits of our treatment: "Mr. Bartlett, I have heard of the benefits of a dozen or more treatments similar to yours, and I must confess I am interested in all of them, but what I desire is a pavement that is hard but noiseless, is smooth but not slippery, is not liable to pit or rut, is neither dusty in dry weather nor muddy in wet; when I find that, I will be satisfied." I merely remarked that "there is a city whose streets are paved with gold, and if you are all right here, you will be all right there."

I afterwards treated some of his local macadam streets and he seems satisfied that there is some hope for an earthly paradise.

Take an ordinary macadam street and, if properly rolled and drained, upon its completion it seems a thing of beauty and a joy forever. Traffic begins and dust mars its beauty, and pit holes or ruts destroy some of the joy of riding over it. You have spent good money in rolling it, and in putting in a binder to hold the wearing surface together. You begin to sprinkle it with water and you wash out the binder and disintegrate the wearing surface. Holes form, water gets into them, vehicle, be it auto or wagon, comes along, spats into them, and out goes the water and with it the life of the road — the precious binder. The water goes back there to lie in wait for the next vehicle, but the binder remains out. And so the process goes on. Then the fall rains come and the macadam becomes water-soaked, the frosts come, and the precious bond is destroyed and your macadam street becomes a soaked sponge waiting for the next frost. And so your money goes, disintegration has begun, and the poor street is an easy victim for ruts, pitholes and more vehicles. Have you ever watched an auto go down a street at a fast clip, and noticed the little ridges of material that follow the wheels? These ridges are composed of the binding material and the dust caused by the abrasion of the surface of the street. Continued traffic grinds this material up and the gentle breezes carry it away.

There is a way to protect the macadam street, and it is the oil treatment. The oil treatment in this locality is a development of the California idea. To the layman all oils look alike, but to those who have studied the problem the oils are divided into two classes: (1) crude oils; and (2) residuum or distilled oils. Again, these are both divided into oils having a base of asphalt, those having a base of paraffin and those having a mixture of the two bases in varying proportions.

A Good Oil and a Bad Oil. — Mr. Prevost Hubbard says on this subject (United States Agricultural Department, Bulletin 34): "The value of an oil as a permanent dust preventive lies in the quality and quantity of high-binding bituminous base retained by the road surface after evaporation of the more volatile constituents. The bases present in petroleums vary from those of almost pure paraffin to almost pure asphalt, many being mixtures of the two. While the paraffin oils are of much more value than the asphalt from a commercial point of view, the opposite is true from the standpoint of their use in dust

suppression. An oil wholly paraffin is of value only as a temporary binder or dust layer, while an asphalt oil, owing to the character of the base contained, ranks with coal tar as a permanent binder."

The paraffin, petroleum residuums are of a soft, greasy character, and, as their name implies, contain a large amount of paraffin, hydrocarbons and paraffin scale or crude paraffin. A road surface treated with material of this character will be dustless for the time being, but in damp, rainy weather will become covered with a slimy, greasy mud, which is easily washed away and leaves the road in as bad, if not worse, condition than it was before treatment. When the crude or even the residual (containing paraffin) is used solely as a binder, it may, therefore, be predicted that the outcome will prove a failure.

As to the treatment: A macadam road built after any good specification is ready for the treatment. The road should be thoroughly rolled and compacted, and should be well drained. The nearer perfect the surface of the road, the better the results will be. The harder the material of which the surface is composed, the less abrasion there will be and, consequently, the less dust there will be for the oil to take up. There are two classes of roads to treat: new roads and old roads. Generally speaking, the treatment is the same and the best results are obtained on the new roads. However, if the authorities are willing, the best way to treat a new road is to apply the oil just before the top or screening course is put on. This treatment must be applied after the street has dried out from the water used in the rolling.

But to return to the beginning of the treatment of an old macadam road, for it is this kind that most of us are interested in. The material or oil: The best material is found to be a partially distilled oil with a heavy asphalt base, with little or no paraffin in it. The removal of the kerosene and other illuminating oils should be accomplished without the "breaking up" of the lighter oils, for they have a very important part to play in the treatment. By taking a distilled oil you secure uniformity of the base and avoid the mixture that may come from crude oils or in the residuum oils.

A material with about 60 per cent. to 70 per cent. asphalt and 30 per cent. to 40 per cent. lighter or so-called petrolene oils will be found to give the best results for surface treatments. The material is usually shipped in tank cars and, where possible, these should be unloaded by gravity. Generally a pump is used to transfer it from the car to the tank wagons. There are several

devices for sprinkling wagons and the only material questions are those of control and equally governed distribution. We now have the street brought to an even surface, properly rolled and well drained. The wagon is at the car filled with the proper material. The street should be thoroughly swept and be thoroughly dry. The sprinkler is driven on and the man behind opens the valves and the treatment is applied. Here again the expert or experienced man is required to govern the flow — too much oil is as bad as too little. Too much oil floods the gutters, fills up the catch-basins, and helps to clog the sewers, disgusts the residents, and a general cry of "Never again" arises. Too little oil leaves a street that is liable to become loose in spots. The small amount of oil acts as a lubricant and allows the stone to work loose. Back of the sprinkler come the men who sweep the oil from whatever depressions there may be on to the high places. The treatment is now complete, but most advocates of oil suggest that a light coat of sharp sand or screenings be spread over the entire surface. This coating will take up any surplus oil and will largely do away with many of the unpleasant features, such as carrying the oil on to the lawns and walks adjacent by dogs or careless people. The street should be closed for a few days to allow the oil to be absorbed by the road material. And now we see why the 30 to 40 per cent. of lighter or petrolene oils should not be "broken up" in the preparation of the material. These are the agents we use to carry the asphalt base into the road metal. A deep penetration is desired. If from 1 to 2 in. can be secured, you will have gained your object. As to the temperature of the oil, it can be applied either hot or cold, according to the fluidity and combination of the base and petrolene oils. But the street must be dry — not a surface dryness, but dry at least as far as it is desired to have the oil penetrate.

This brings us to one of the important points in the treatment of streets with oil. There are two great objects to be gained in this treatment of streets: First, the elimination of the dust nuisance; second, the preservation of the road surface.

In discussing them let us reverse the order and begin with the preservation. We take the street again in the condition as near perfect as it can be brought. The oil is applied and the combination of the asphalt base with the petrolene oils is carried down into the road surface and we have the asphalt acting as a binder. It is, in fact, a matrix that holds the road metal in position so that the wear is all on the stone, and this often causes an oiled street to look like a black and white mosaic pavement.

In the course of a few days, depending upon the weather conditions, the lighter oils evaporate or disappear and the asphalt remains. This asphalt acts as a waterproof and causes the rain to seek the gutters at once, so that very soon after the storm the street is as dry and as clean as a cement sidewalk. These two points, first, causing the road metal to remain in place and take the wear, and the waterproofing of street surface, are the ones that are the great preservative features of this treatment. If the road metal is held in place so that it takes the abrasion only on one surface, and the independent units are so firmly held that they are not irritants to each other, we have done away with a large part of the grinding up or wearing away of the pavement, and thus eliminated the pit holes or ruts. If the water is kept out of the pavement it will not become soft in spots and thus shove or push and so make depressions.

Now as to the elimination of the dust nuisance. You have seen that we first removed most of the loose dust from the street before treating it so that now all that can be raised is that caused by the abrasion of the surface after treatment, or that which is brought on. We do not claim that the oil treatment is a cure-all for the ills of macadam pavement, but it is the best that has yet been discovered, and this is how it works. A macadam road after it has been swept will show, upon close inspection, a rough surface composed of the individual units of the road metal set in a binding material and will appear like the rough concrete sidewalk before the top or fine stuff is put on and troweled. The oil when applied soaks down or is carried into the surface, going into the binder and the voids faster than it does into the road metal. Thus it surrounds the units and holds them firmly as a matrix. The traffic comes and the hard road metal takes the wear and abrasion. The fine particles of it, instead of, as before treatment, being blown away, are now carried forward or sideways into the matrix of asphalt, and they in turn become part of the wearing surface. When new dirt, either dust from side streets or droppings from the traveling animals, comes to the street, the same thing occurs, and it is forced into the asphalt binding, and thus there is very little dust.

You doubtless have noticed on the oiled roads you have observed that on each side, plainly marked out from the lines of traffic, are windrows of foreign matter that has been brought to the street and has been whirled to the sides by the swiftly moving vehicles, particularly the automobiles. That this foreign matter is not whirled into the air to be carried to the houses to destroy

furnishings, and to the people to destroy comfort and perhaps health, is due to two particular properties of properly prepared asphalt oils: First, the asphalt oil's remaining alive, whereby it is able to accommodate to itself or to hold in itself more and more foreign material; and second, its viscosity or stickiness, which holds or tends to hold the lighter foreign matter to itself long enough to allow the suction force of the vehicle to just move it out toward the gutters. Right here let me say that this stickiness is not offensive after the street is properly cured or dried. By this I mean it does not remain so sticky that it can be carried off by the shoes of pedestrians or by the tires of vehicles passing over it.

Now having eliminated the dust nuisance and rendered the street waterproof, we can take up the matter of the saving of expense in cleaning and caring for the street. We all know that before treatment the macadam road always had more or less of loose road material on its surafce, and when swept by men or by rains this accumulated in the gutters and had to be hauled from them or taken from the catch-basins. The sweeping of the street itself required some skill to avoid heavy pressure on the brooms that would loosen the surface, and thus hasten the decay of the street. One superintendent of streets told me that he averaged five loads of dirt every time a certain street was swept, but that since the treatment he did not sweep the street half so often, and did not get a full load when he did. And not only that, while the street always is cleaner than formerly, he now does the sweeping by a machine, which was impossible before the treatment. I will take up sprinkling with water later.

Now a word for the poor automobilist. He is blamed for the wearing out of the macadam streets, when he only hastens the inevitable; he is blamed for the dust nuisance, when he only, in proportion to his size and speed, emphasizes the need of a remedy. Let us look at the effect of an automobile on a macadam road before and after the oiled treatment. Before: The pneumatic tires on the heavy machine are compressed and widened so that the convex surface becomes flattened, and, in going, forms a rapidly moving vacuum. This sucks the binder out of the macadam and leaves the stones loose. The binder is blown away and the loosened stones become irritants that aid in loosening their neighbors. Soon a hole begins and rapidly goes from bad to worse. After treatment: The pneumatic tires have the same action, but instead of having the loose binder to work on, the asphalt base takes the suction force and the machine acts the

same as a gentle padder and draws the asphalt to the surface and irons out any loose particles or holes that have been caused by the horses' shoes or the steel tires of other vehicles, and so from a destroyer, the autoist is made a preserver of a macadam roadway, after the oil treatment.

My experience in this work has shown several fallacies that most beginners seem to have.

First. — Most people want an asphalt coat applied to their road; and here is a grievous mistake, for it is not reasonable to suppose that a coat varying from $\frac{1}{16}$ to $\frac{1}{2}$ in. can be put over a road and withstand any traffic unless the coat is made of boiler iron.

Second. — Many people believe that when there is a dry surface the road is ready for treatment. They forget that our material is oil, and that most oils will float on water, so it is folly to expect that the oil will penetrate farther than the moisture line or depth.

Third. — Many in charge of roads desire you to flood their streets with oil. This is not only a waste of good material, but it is a positive detriment to the growth of a sentiment in favor of the treatment, for it disgusts those who are sponsors for it, and gives a weapon to its enemies.

Fourth. — That this treatment is ruinous to rubber tires. Hot asphalt is also ruinous, and so is any oil if the rubber is soaked in it. If the tire owners will keep off the material until it is set or dried, they will join the ranks of the boosters.

Fifth. — Most people expect for the small cost of the first treatment to obtain all of the benefits that come with one of the higher cost pavements, with none of the disadvantages of it.

The cost of this treatment will vary largely according to the cost of the material — for it can be had for from two to ten cents per gallon, — the condition of the street, the distance from the switch and the amount of work to be done. A very satisfactory job can be done at a cost per square yard of from five to nine cents. As to the number and frequency of treatments, this must be governed largely by the local conditions, of quality of street, kind of traffic and amount of traffic. I advise one treatment each for the first two years; this enables the second treatment to take out most of the original depressions that were not taken out by the first treatment. After that the treatments are a matter of judgment on the part of those in charge of the roads, but a fair average would be three treatments in five years.

I have thus far taken the road as if it had been in perfect

condition at time of treatment, but this is the ideal and rare case. Generally the road is an old one, worn by hard traffic and the oil man is supposed to make it perfect in one treatment at the small price named above. He can make it perfect, for he can rebuild it, or he can do the best possible with the conditions he has to face. This is his usual task, and his results are then compared with a new pavement of some other high-priced kind, and aside from the alleviation of the dust nuisance, his work is voted a failure.

Let us go back to our figures. Macadam pavement of either kind costs from 80 cents to $1.10 per square yard. Three treatments at 7½ cents per square yard is 22½ cents, and here at a maximum cost of $1.30 we have a pavement that has lasted five years, has been dustless and without mud all the time, not only in June and September, but in March and November, and has as few holes or depressions as any other pavement of the same age that has cost 75 per cent. more. The cost of repairs, maintenance and cleaning will be nearly equal, and we have avoided all of the noises that the other pavements cause or permit. The question that confronts those responsible for our roads now is, What to do with the miles of old macadam roadways we have, and whether to continue to build more of this class. This question seems to be answered in the continued success of the oil treatment.

A word concerning the sprinkling of macadam streets with water. This is the expedient adopted by many, and it is virtually an acceleration of the decay. Scientific sprinkling with water will tend to allay the dust, but on hot days it requires a large number of applications, and even then the street will be dusty part of the time, and more or less muddy the rest. Sprinkling with water cannot be done in the cold months when it is freezing or the streets will be too slippery, and that is the time when the dust will surely fly; and so it seems that, compared with benefits derived and duration of results, sprinkling with oil is as cheap as sprinkling with water.

I spoke concerning penetration and coating a little while ago. I wish now to emphasize these, as they are very material in a discussion of this treatment. It is absolutely essential that the first treatment should penetrate, for if it does not, no following one will ever go below or through it, unless the entire surface of the street is scarified. The treatments after the first revivify the asphalt in the first one, and do put a coating on the surface of the street. But this is not a coating in the sense that it is something laid over the surface like a sheet, but rather it is like

another course of concrete in that it is bound to and set with the one that has penetrated, and thus we have from $1\frac{1}{2}$ in. to 2 in. of an asphaltic concrete with limestone or granite forming the coating.

The benefits derived from the treatment of macadam roadways with asphaltic oil are the absolute elimination of the dust nuisance and the preservation of the road surface. At a small cost you make a roadway that is pleasant to the eye, beneficial to your horses and vehicles and a delight to ride over. The treatment has come to stay, and each year will see a greater mileage covered, for it answers a long-felt want and settles cheaply a very serious question.

So much for the oil treatment of macadam roads. Country roads and dirt roads or cinder roads can be treated with the same material, but not in the same way. Here the road is treated, then harrowed, then treated again, allowed to dry or set, then rolled to as hard a condition as possible, then treated again. With this treatment by men who know how, a road that is dustless, waterproof and mudless can be made at a less cost than any other kind of pavement can be put down. You have all heard of the California roads, and that, roughly, is how they are made.

Where the asphaltic oil is used in the construction of new macadam roads, a heavier percentage of asphalt base can be used to good advantage.

A few suggestions as to care in use of asphaltic oils may not be out of place.

Be careful to get an oil that contains little paraffin or sulphur, and in which the lighter oils have not been "cracked" in the removal of the illuminating oils. If a crude oil is used, be sure that the oil is of the same constituents in the same proportion in each shipment. Keep traffic off, at least until the oil has had some chance to penetrate or set. Try to get as much chance for your roadway as you would if putting down a new pavement. Do not tell people that you can make a new asphalt street out of an old macadam pavement in one treatment with asphaltic oil.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by May 15, 1910, for publication in a subsequent number of the JOURNAL.]

SUN RIVER PROJECT, MONTANA: UNITED STATES RECLAMATION SERVICE.

By S. B. Robbins.

[Read before the Montana Society of Engineers at its twenty-third annual meeting at Butte, Mont., January 8, 1910.]

Sun River is one of the more important tributaries of Missouri River, heading against the Continental Divide in the Lewis Range and, after emerging therefrom, flowing almost due east to its confluence with the Missouri at Great Falls. The bottom lands vary from one to three miles wide, and the bench, which is so familiar in Montana topography, stretches away mostly on the north to the next valley, that of the Teton River.

In the territory embraced between Teton and Sun rivers west of the Missouri River there lie over a million acres of excellent farm land, the area of which reclaimable is dependent upon the water supply available. The run-off from Sun River indicates that with proper storage facilities there should be water available for some 300 000 acres more than now irrigated by private means under prior appropriations. The quality of the soil, the elevation, the vicinity of the growing center at Great Falls make the reclamation of this area attractive from the viewpoint of the settler and important from the viewpoint of those interested in the upbuilding of Great Falls, its vicinity and the state. Briefly, the irrigation plan of this project contemplates the construction of a storage reservoir on the North Fork of Sun River controlled by the Warm Springs Dam, storing the flow of this branch of the river. The capacity of this reservoir is 157 000 acre-feet. A possibility exists for a dam site immediately below the forks of the river, backing water up each fork, although the expense in connection therewith has not thus far been deemed expedient and, prior to the need of this storage, the development of the country may be such that the more expensive and larger reservoir will be an advisable and profitable investment. From the upper reservoir the water will flow in the natural channel of the river to the canyon where it leaves the mountains. At this point a diversion weir of reinforced concrete, 72 ft. high, 150 ft. long on the crest, is planned. The

type of the dam planned at the Warm Springs site is loose rock fill with hydraulic backing. Maximum height will eventually be 213 ft., and crest length, 762 ft. The spillway would be behind a butte some 500 ft. higher than the crest of the dam into another fork of the river, the outlet leading through solid diorite.

From the diversion weir in the canyon the main canal will be taken through tunnel No. 1, a distance of 5 000 ft. It is planned to construct a branch tunnel from this at the end of the first 1 000 ft. and carry the South Supply canal in a flume across the canyon where its width is about 60 ft.; thence an open canal for 8 miles to the summit between Sun River and Willow Creek, from which point it will discharge into another channel to the Willow Creek Reservoir. This reservoir will have a capacity of 84 000 acre-feet. The dam for Willow Creek Reservoir is now under construction. It is to be of earth and ultimately 110 ft. high, but temporarily built to height of only 70 ft. until the reservoir is later supplied from Sun River. The outlet works will consist of a tunnel 584 ft. long and 4½ ft. in diameter, and a diffusion chamber at the outlet end for destruction of excessive velocity and the measurement of the discharge. The control will be by a 54-in. circular sluice-gate manufactured by Chapman Valve Company, operating through a 65-ft. shaft. Construction has progressed to the extent of driving and lining the tunnel and the sinking of the shaft preparatory to lining. The stripping of the dam site has been completed and cut-off trenches partially done, materials and supplies assembled for the prosecution of the work at the opening of the season 1910.

From this reservoir water will be allowed to flow in a natural channel to the Fort Shaw headworks, thence taken up on the Fort Shaw unit already constructed and in operation. Also it is expected to supply prior appropriators below the reservoir along the river with stored water in lieu of low-water flow, which may be diverted to supply the North Side lands.

The large area of the irrigable lands lies to the north of Sun River between it and the Teton. From the canyon the North Supply canal will carry water into the Pishkun Reservoir, which has a capacity of 46 000 acre-feet. This reservoir is so situated that water may be discharged either into the High Line canal running along Sun River slope or through a 430-ft. tunnel into the drainage of Teton River. The High Line will supply the lands lying on the upper benches on the Sun River side and on the Greenfields Bench. After leaving the Pishkun Reservoir, water will follow natural channels about 12 miles through

Teton slope canal headworks on Deep Creek; thence it will follow eastward to supply land on the south side of the Teton to a point some 20 miles east of the Montana & Great Northern Railroad. There will be two interesting features on this canal in the shape of pressure pipes, one of which at Priest Butte will be 4 400 ft. long and with a diameter something in excess of 10 ft.; the second, at a crossing of the Montana & Great Northern Railroad, will be some 2 500 ft. long and some 6 ft. in diameter.

Lying directly north of Great Falls about 8 miles is the old Benton Lake bed, which it is expected to utilize to hold the flood waters of Deep Creek and such unusual floods of Sun River as may be obtainable. It will be necessary to construct an additional canal only about 5 miles long to throw these waters into the lake, and it is hoped to reclaim a sizable area in the vicinity of Great Falls from this storage, although the exact area cannot yet be determined until the available supply of water is better known.

Another interesting feature is the expected diversion of Bowl Creek, a small branch of the Flathead River, across the Continental Divide into Sun River. This is less spectacular than it would appear to be, as surveys indicate that a mile and a half of open canal will secure the result, the spectacular feature being the crossing of the Continental Divide.

Altogether in the project it will be necessary to drive something in excess of 2 miles of tunnel and construct probably 2 500 miles of canals and ditches of all classes.

Fort Shaw Unit.

Water is taken directly from Sun River through four steel headgates 4 ft. by 4 ft. in reinforced concrete headworks. The grade of the canal at this point is 3 ft. lower than the bed of the river, thus obtaining proper depth of water without any dam; 105 miles of canals and ditches were constructed on this unit and some 16 000 acres can be irrigated therefrom. Water is delivered to each farm, and the system is built in its entirety, leaving no laterals, drain ditches or other work to be done by the settler or water taker other than that incident upon his private agricultural operations. The most interesting features at Fort Shaw are the Simms creek pressure pipe, 1 565 ft. long, 5 ft. 4 in. inside diameter, capacity 175 second-feet, head-on pipe 50 ft., thickness of shell 6 in. This pipe was carried across the creek bottom on piers, because the grade of the valley was

so slight that in order to drain the pipe an excessively long cut would have to be made and maintained. This feature is somewhat novel and has worked very satisfactorily, notwithstanding the fact that in the excessive floods of 1908 the openings beneath the pipe were insufficient to carry the flood, and this entire portion was submerged, the water flowing over the top some 6 in. in depth.

It has been necessary to make several drops in various places, descending from one level to another, and it has been the endeavor to imitate nature as nearly as possible and utilize the materials at hand to secure these results. The A drop discharges 50 second-feet a vertical height of 50 ft. It is a smooth, concrete lined, trapezoidal section, ending in a stilling pool where the currents impinging upon themselves deaden the velocity of the water, and it flows thence through distributing boxes into the earth laterals.

C drop carries 75 second-feet a vertical height of 80 ft. in a distance of 750 ft. The headworks for this are reinforced concrete and the drop itself consists of trapezoidal channel loosely paved, with bowlders of two or three cubic feet in size staggered throughout its course, projecting above the general elevation of the paving to kill the velocity after the manner of the bed of a mountain stream. This paving was filled with coarse concrete grout, and a stilling pool of earth paved on the side opposite the current was made at the lower end of the drop and at the intake of the lateral. It was thought that some velocity might exist necessitating this stilling pool, but operation has disclosed the fact that the velocity was so deadened that the pool is silted up with the exception of a well-defined channel from the end of the drop to the entrance of the lateral.

Construction was started on the Fort Shaw unit in May, 1907; water was turned on July 21, 1908. There were 206 public land farms at the time of opening the old Fort Shaw reservation for entry, the average size being 88 acres, of which 61 acres are irrigable. At the end of 1909, 132 farms have been taken, a total of 12 136 acres, of which 7674 are irrigable.

It has been considerable of a surprise to the project engineer to discover that the popular demand has been for small farms rather than the large ones. It was expected that the larger irrigable areas, particularly those farms containing considerable dry land, would be eagerly sought at first, and the smaller tracts, particularly those all irrigable, would be a drug on the market until some later date. Quite the reverse has been true,

and this fact has been noted elsewhere the past season on private projects.

The progress of construction and future development being dependable upon the condition of finances and approval by the Washington office, it cannot be known definitely what progress will be made or at what time the project can be completed in its entirety.

The total estimated cost of the Sun River project completed is eight and a half million dollars.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by May 15, 1910, for publication in a subsequent number of the JOURNAL.]

ANNUAL ADDRESS.

By J. T. Eastwood, President of the Louisiana Engineering Society.

[Read before the Society, January 8, 1910.]

Under the provisions of our constitution, it becomes my duty, as President of the Louisiana Engineering Society, to address its members at this, our annual meeting, to give some account of my stewardship, to explain our work during the twelve months I have been your President and to make any suggestions from the experience of that year for the betterment of the Society. I know very well that on an occasion of this kind you do not want from me any technical talk on engineering questions or problems, and I shall, therefore, confine myself to "Our Society, its Present Status and the Outlook for the Future"; in other words, what we have together done during the year to strengthen the Society and to carry out the purpose for which it was organized. These are specifically stated in our constitution to be: (1) The professional improvement of members; (2) the encouragement of social intercourse among engineers and men of practical science; and (3) the advancement of engineering.

These are great and noble purposes, beneficial to us professionally as well as to the whole community. How far have we carried them out? This is distinctly an engineering age; at no time in the history of the world has our profession ranked higher or undertaken greater and more important enterprises. At no time has the advance of engineering been more rapid; more new ideas, new methods, new mechanical devices, brought into use; it is an age of opportunity for the skilled engineers of this country, for we are reaching out to Panama, Hawaii and the Philippines to take up work that has been waiting centuries to be done; here in Louisiana and New Orleans the same engineering zeal and energy prevail, the same great enterprises, so long delayed because we lacked the engineering skill or capital to carry them out, are being undertaken and rigorously pressed to early completion. Louisiana will soon complete its levee system; it has taken up the work of drainage, and we can safely predict that in the lifetime of the present generation every one of the millions of fertile acres, which have lain useless since the

beginning of time because subject to overflow, will be redeemed by drainage and brought into cultivation, while our long stretches of bayous and open waterways will be opened to navigation; it should be a matter of no small satisfaction to us that the members of this Society have borne a conspicuous part in all of these enterprises.

Here in New Orleans millions of dollars are being expended on the greatest and most difficult of engineering work — to provide drainage and a sewerage system to the city, to let the water out by drainage and keep it out by levees, and to solve the problem of a good water supply, the lack of which has seriously handicapped New Orleans in the race of progress from its birth; in all of these works new problems face the engineer, and new methods of apparatus became necessary to solve the many difficult problems presented.

What has our Society done to help along this good work? It is a strong body, one of the strongest in the country, with nearly one hundred resident members, and nearly one hundred and forty throughout the state, and it includes in its membership men of national reputation. The Society is well-known throughout the country, thanks to the Association of Engineering Societies; and it has been well advertised; the eyes of the country have been turned on New Orleans and Louisiana to see what is being done here to solve the problem of a drainage system and a good water supply, and many men of the highest standing have visited the state and city to see and examine the work being done, the difficulties encountered and conquered; this is what the Society organized to do. It has done much good on these lines; that it has not done all it could have done all will equally admit; let us consider, then, among ourselves what we can do to fully carry out the purposes for which this Society was organized and to raise the profession of engineering to a higher plane. All we do honestly and earnestly will be for the benefit of the state, the city and the people, for their convenience, comfort and health; to develop commerce and business and assure general prosperity. New engineering works not only assure all these great benefits, but they open possible investments for capital and employment for labor. Had engineering work been as stagnant in the last ten years as previously, tens of thousands of persons would have suffered for lack of employment. As it is, thousands of persons have been fed and clothed by engineering enterprises which the members of this Society have framed and carried out.

The present era is conspicuous especially as an era of activity, and this activity as pertains to ourselves is interesting, especially along the lines of technical education and engineering accomplishments. The time is past when men strove to fortify themselves with private knowledge and to maintain a certain excellence by means of secrecy; the dissemination of knowledge, with but a few notable exceptions, has become universally a national problem, and not only is this accomplished by an elaborate and efficient school system, but by the researches and experiences of practical men, and in all professions those of us with common interests have organized into societies and clubs, for the purpose of acquiring a broader view of each other's work than perhaps time, opportunity or inclination would otherwise permit. It was for such purposes and reasons that the Louisiana Engineering Society was organized, and its success may be judged by its relations directly or indirectly with many enterprises of this city and state. The Society does not claim responsibility for the achievement of these things, but we know that the high standards and encouragement put forth by this organization goes far toward the accomplishment of the tasks of its members and the conception of new engineering schemes. In this connection, I call to your mind the great sewerage, water and drainage work which is being executed by the Sewerage and Water Board under the immediate direction of engineers who are members of this Society. This work has been in continuous progress for the last nine years, with the result that the sewerage system is about 90 per cent. completed, the waterworks system 95 per cent. completed and the drainage system 50 per cent. completed (covering the present built-up area), involving a total expenditure of approximately $19 000 000 to date. I will also mention the great street paving work now in progress, and bridge construction being done by the city of New Orleans under the direction of the city engineer. Also, the great system of levees and drainage being executed by the state under the direction of the State Board of Engineers; also the great and splendid system of docks being built by the Board of Commissioners of the Port of New Orleans under the direction of members of the Society. All of the above works are being principally executed under the direction of members of this Society.

Perhaps the greatest problem that has come before this nation in recent years has been that of the conservation of our national resources, and this problem is strictly an engineering

one in all its different aspects. It is the office of the engineer to construct where others destroy, to economize where others are extravagant, and to render the resources of nature subservient to man; the development of the South is a question occupying the attention of both capitalist and philanthropist, and the state of Louisiana offers its mining, its agriculture, its fisheries, its manufactures, its waterways and its water power, inviting expenditures of money and mental energy for their betterment and members of this Society are engaged in some manner in all these varied interests to better the product or to increase production, making now grow two blades of grass where previously grew one. Notable under civil engineering, we have the reclaiming of heretofore overflowed territory and making the same suitable for habitation. In electrical engineering we have the central electric station of the drainage system of New Orleans, which operates the various substations in the drainage system. In mechanical engineering we have the beautifully equipped water-works pumping station, with four 20 000 000-gallon high-duty pumping engines; and in sanitary engineering we have the sewerage, water and drainage systems, which have received the approval of the highest authorities in this country.

It would be well for the individual members of this Society to keep in mind the fact that the most important side of all engineering work is the economic side, and in just such proportions as we succeed or fail to-day will future generations enjoy or suffer the results of our work.

The beginning of the twentieth century has witnessed the great achievement of the transmission of intelligence by wireless telegraphy, the conquering of the air by the flying machine and the discovery of the North Pole. In a few years we shall witness the completion of the greatest work in secular matters to which the hand of man has been put,— the cutting through the Isthmus and uniting the two oceans, all of which is the work of the engineer.

The engineering outlook for the future is bright just now; our work, like everything else, is affected by the depression; newly planned enterprises were held back and the work on older ones carried on slowly; money was hard to get; but with the return of prosperity, all these enterprises are being rushed forward, and we may regard the situation as promising to all members of our Society. There is no surer barometer of prosperity than engineering activity. The future ought to be equally promising to the Louisiana Engineering Society; it already compares with

similar societies throughout the country in its membership, and the names on its roll; but it ought to bring in a number of new and younger members and thereby strengthen itself; and this it can do if it will carry out fully and faithfully the purpose for which it was organized. I should not be doing my duty as President if I did not call attention to some weaknesses which need attention. The Board of Direction have done all in their power to advance the Society, but they have not received the cordial support of all the membership in this work; there has been a lack of attendance at the meetings, which has had a discouraging influence; there has been a lack of discussion on papers read, whereas the best results follow from such discussions and exchange of experiences; and I would, in this connection, call attention to similar discussions of papers read before medical and other societies, whereat every member present joins in and gives his experience, with the result that all there present get the combined experience of a score or more of experts on the subject under discussion. The members must be interested in the work, and I fear that too many dry papers on technical questions keep them away from the meetings; these should be enlightened in some way, made more attractive. Let us not forget that while one of the purposes of the Society is the promotion of engineering, another is "to encourage social intercourse among the members," the importance of these social relations being fully recognized. I suggest in this connection the appointment of a special committee to look after meetings, to arrange an attractive program, to provide amusements that would attract to these meetings not only the resident members, but engineers from all parts of the state. We must encourage young engineers to join the Society. I know that the average engineer is jealous of his work, for his knowledge is his power, but there is much he can give to others without in any way reacting unfavorably upon his own work, yet tending to the advancement of this Society and the profession of engineering. I would suggest also that the Society secure a permanent home, which we can fit up, make agreeable, and which, with our fine library, will be attractive to resident and visiting engineers.

I wish to thank the members and the Board of Direction and especially the Secretary for their hearty and generous support given me during the past year. With these words I resign my presidency and turn it over to Professor Gregory, of Tulane University, under whom we all know the Society is certain to advance and improve.

OBITUARIES.

Earle Harley Gowing.

MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

EARLE HARLEY GOWING was born in Woburn, Mass., July 10, 1853, and died in Millinocket, Me., November 24, 1909. His parents were Ames Gowing, born in South Reading, Mass., and Emma Genevra Reed, born in Boston, Mass. He was the seventh lineal descendant of Robert Gowing, who was born in 1618 in Edinburgh, Scotland, and came to Dedham, Mass.

His grandfather, Jabez Gowing, lived in Concord, Mass., and, being near the district school, he lived with his grandfather when school was in session. After his parents removed to Reading he entered the high school in that town, graduating in 1872.

At an early age he displayed great interest in steam engines and other mechanical appliances, and during his school years in Reading he spent considerable time in a cabinet shop, where he showed much ingenuity in the construction of an oak sideboard and bookcase.

He entered the Massachusetts Institute of Technology in 1874 as a special student in civil engineering, remaining until 1877. While at the Institute he showed ability and originality in his work, which showed its results in his profession in later life in solving difficult problems. After leaving the Institute in 1877 he entered the George F. Blake Manufacturing Company's shop in Cambridge to learn the trade of machinist in its practical bearing on his profession. He remained here until 1880, when he accepted a position with the Deane Steam Pump Company, working in the shop at Holyoke and in the office in New York City, and later in St. Louis. He attended to the general repair work and familiarized himself with the details of the business. In 1883 he became assistant to George H. Barrus, consulting steam engineer and expert, and in connection with this work he took a leading part in charge of one of the watches on Mr. Barrus's 144-hr. test of the Reynolds pumping engine at the Detroit Water Works, and on a later occasion he served as Mr. Barrus's leading assistant on a series of road tests of locomotives made for the Baldwin Locomotive Works on the Baltimore & Ohio Railroad.

From 1885 to 1888 he was engaged with B. C. Mudge, New England agent for Henry R. Worthington, selling pumping machinery, and later he constructed water works in Bath, Skowhegan and Eastport, Me., and in Grafton, Mass. From 1888 to 1891 he completed the unfinished water works in Skowhegan, Me., and built water works at Fort Fairfield in addition to being engaged in general engineering work.

In 1891 he entered into partnership with John J. Moore, of Hingham, Mass., under the firm name of Moore & Company, with whom he was associated at the time of his death. The present offices are in the Pemberton Building, Boston. The firm is engaged in engineering and the construction of public works, making a specialty of water works and general contracting work. Among the water works built by this firm may be mentioned those at Whitefield, Lancaster, Gorham, Colebrook, N. H.; Boothbay Harbor, Phillips, Newport, Millinocket, Van Buren, Searsport, Dixfield, Me.; Scituate, Mass.

In many of these water works the firm owns a controlling interest. The extent of its business may be judged by the fact that some 1600 miles of water pipe, have been laid ranging in size from 4 in. diameter to 48 in. diameter. The firm is a large user of the Ward joint for pipe laid across rivers and has probably employed this joint more than any other contractor, excepting the inventor himself. Mr. Gowing particularly enjoyed overcoming difficulties that arose in connection with his work, especially in regard to pipe-laying across rivers, when it was customary for both himself and Mr. Moore to don diving suits and make personal examination of the condition of the bottom of the stream and the joints of the pipe, and on at least one occasion he disdained the use of the diver's suit and made an examination in 7 or 8 ft. of water. During this period Mr. Gowing served as engineer of the water works at Machias and Oakland, Me., and engineer of the works at St. Johnsbury, Vt. He was one of the commissioners to appraise the value of the water works at Farmington, Me., and one of the commission for valuing the works at North Conway, N. H.

In 1891 Mr. Gowing entered into partnership with Mr. Barrus under the firm name of Gowing & Company, and published the book of "Boiler Tests," written by Mr. Barrus, followed later by the publication of "Engine Tests." This firm put on the market the Barrus Universal Steam Calorimeter and his multiplying draft gage, besides doing considerable experimental work with apparatus for measuring carbonic acid in

flue gases, with an integrating steam engine indicator, with automatic stokers, and with other subjects allied to engineering.

Mr. Gowing was the inventor of the Gowing Jointer, a device for making joints in cast-iron water pipe, which has had a large sale.

Mr. Gowing was the founder of and, with his partner, a large owner in the Millinocket Trust Company, Millinocket, Me. It was in their building, where he had gone for a few days to take the cashier's place in his absence, that the gas explosion occurred which caused the terrible injuries resulting in his unfortunate death.

Mr. Gowing was president and promoter of the Whitehead Association at Nantasket, which a few years ago developed the Nantasket Point property as a summer and pleasure resort. In this connection he was also president of the Hull and Boston line of steamers that ply between Boston and Nantasket Point.

He was engineer and promoter of the Hingham Street Railway Company, now owned by the Massachusetts Electric Companies, and he held offices in other companies as follows: President, Colebrook Water Company; treasurer, Phillips Water Company; treasurer, Millinocket Water Company; treasurer, Millinocket Light Company; treasurer, Frontier Water Company.

He was a director in all the above companies, as also in the following: Searsport Water Company, Dixfield Water Company, Scituate Water Company, Cohasset Water Company, Liberty Trust Company, Boston.

Mr. Gowing was a member of the water board of Reading, Mass., where he had been engaged for the past five years in investigating methods of purifying and improving the water supply.

He was also a member of the following societies and clubs: Boston Society of Civil Engineers, New England Water Works Association, Technology Club, Exchange Club, Boston City Club, Economic Club, Boston Yacht Club, Unity Yacht Club, Porter's Yacht Club, Good Samaritan Lodge, A. F. and A. M., Reading; Melrose Lodge, No. 1031, B. P. O. E.

Mr. Gowing, with his partner, for many years owned the pleasure yacht *Diamond* and made frequent use of this during the summer season for the entertainment of friends and business associates. There is hardly a person with whom he had dealings, either of a social or business nature, who has not been the recipient through this means of his generous hospitality.

Combined with his commercial and engineering ability,

Mr. Gowing had considerable taste for legal matters in so far as they pertained to his interests. He was in the habit of drawing up his own contracts, charters and corporation papers without legal assistance. These were so complete that Attorney-General Haines, of the state of Maine, who was a close friend and business associate, said they could not be excelled even by the best professional lawyer.

One incident in Mr. Gowing's experience may be mentioned which illustrates the wide range of his ability. A 600-ton schooner was wrecked off Nantasket and condemned by the insurance company as a total loss. The Boston Tow Boat Company went so far as to say that the boat could not be raised. Mr. Gowing saw the matter in a different light, purchased the wreck for a trifling sum, raised and repaired her, fitted her out for service, and in two years was repaid all the money that had been expended and a handsome profit besides. Although the boat was an English vessel, Mr. Gowing succeeded in putting her into service under the American flag without the aid of any international lawyer.

Mr. Gowing was a leader of men. He once told an intimate friend that nothing gave him so much satisfaction as to succeed in an undertaking which depended on his bringing such an influence to bear on the men interested that they would finally come to indorse his views and help him on to success. This may be due to one characteristic of his life which was exceedingly marked. He had the courage of his convictions, and it mattered not whether they were shared by friend or foe, he acted upon them and was true to his ideal.

During the three years of intimate association with him at Technology, his earnestness in his work and loyalty to all traditions of school, professors and classmates, won the respect of all. His long service as quartermaster in the school battalion and leadership in the political torchlight parades are events well known to his classmates, and his skill was more recently brought into play at Nantasket in the Tech reunion during the past year. His interest in Technology has been shown by his attendance at class reunions and general meetings of the alumni. Although not an active worker directly in any religious organization, he had the cardinal principle of doing his work thoroughly for the sake of having it right, and he was always a believer in having honest work carried out in such a manner that each completed job should be a certificate of thorough and satisfactory work. With his conscientious work in this world he has built a founda-

tion of character that will leave its impression behind him and will serve for further extension and usefulness in the future world with broader opportunities before him.

Mr. Gowing married Isabelle P. Dinsmoor, September 16, 1883, and has always made his home residence in Reading, Mass. Mrs. Gowing and an adopted daughter, Margaret, eighteen years of age, survive to mourn his loss.

RICHARD A. HALE,
LEWIS M. BANCROFT,
Committee.

Charles Clarence Bothfeld.

MEMBER OF DETROIT ENGINEERING SOCIETY.

BORN September 7, 1860. Died November 20, 1909.

THE subject of this brief sketch, Mr. Charles Clarence Bothfeld, was born in New York City, September 7, 1860. His father was a civil engineer, employed in the service of the United States Engineering Department. The family removed to Boston in 1868, and Charles's early education was in the public schools of Newton, Mass., with graduation from the High School in 1877. He graduated from the Massachusetts Institute of Technology with the class of 1884 and took his degree in civil engineering. After graduating he was employed in the Engineering Department of the Edge Moor Iron Works at Wilmington, Del., where he remained about one year. He then entered the Keystone Bridge Works at Pittsburg, Pa., where he remained two years in the Estimating and Designing Departments. He then accepted a position with the Pittsburg Testing Laboratory and was called to Toledo to act as bridge engineer for the Toledo, St. Louis & Kansas City Railway Company and had charge of the construction of a large number of bridges for this road and for the Cleveland, Akron & Columbus Railway Company.

He came to Detroit early in 1889 and established himself as a consulting and inspecting engineer. He acted as consulting engineer for the Hocking Valley Railway, Toledo & Ohio Central Railway and the Toledo, St. Louis & Western Railway, and at various times did either consulting or inspection work for over thirty railway companies. He designed several highway and electric railroad bridges and viaducts, among which was a

bridge across the River Rouge and the approaches to the Belle Isle Bridge. He also supervised the inspection of material and erection of many of Detroit's important buildings. He was elected a member of the Detroit Engineering Society, May 1, 1896, and his death occurred November 20, 1909.

He had great ability and tremendous energy. He worked hard and fast, but for some years his health was not of the best and his activity was a drain on his strength. To those who knew him best he was a friend who stood fast in every trial, loyal to the extreme. He gave quietly to many charities and was most generous when his sympathies were enlisted. He was fond of social life and was a member of several local clubs. He was witty, entertaining and fond of a good joke, and, above all, was true and sincere.

His loss will be keenly felt by his large circle of friends in engineering, business and social circles.

O. W. Albee,
F. C. McMath,
Committee.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

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COST OF POWER FOR VARIOUS INDUSTRIES UNDER ORDINARY CONDITIONS.

BY CHARLES T. MAIN AND F. M. GUNBY, MEMBERS BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, December 8, 1909.]

TWENTY-FIVE years ago the expression "cost of power" was fairly well defined as meaning the yearly cost per indicated horse-power if produced by steam; or power on the wheel shaft if produced by water for 10 hr. a day and about 308 days a year, or for 24 hr. for the same number of days. This was fairly well understood by those who had to deal with these matters and who gave the matter any thought.

Since that time, when mechanical transmission of power by shafting, belting, ropes, etc., were about the only methods in use, there has been developed the electrical transmission of power now so commonly in use, with new units of power, as electrical horse-power and kilowatts.

Also there has now come into common use the steam turbine, for which there is no indicated horse-power, the measurements of power from which must be brake horse-power, electrical horse-power or kilowatts. There is the power produced by water wheels, which is gross horse-power, net horse-power at the wheel shaft and, when transformed into electric power, it is measured in electrical horse-power and kilowatts.

New industries like public lighting and street railway

companies have also come into existence. In these plants, the cost of power is affected very greatly by factors which were unknown to the type of plant which was common to industrial concerns of the past.

So to-day the statement, "cost of power," unless clearly defined, may mean one of many things, and the men who are used to thinking in the units and figures common to the old type of plant are sometimes at a loss to know what is meant when the cost is stated in some of the newer ways, as, for instance, so much per kilowatt hour, delivered. These figures must be translated back into indicated horse-power or its equivalent before any definite impression is made on their minds. Even then they may be at a loss to understand why the costs are so different from the ones they have in mind as a basis of comparison. It is the object of this paper to explain briefly some of the reasons for the very great differences in the cost of power under various circumstances, hoping that these explanations may be of value to those who have to deal with these matters. It is our intention to treat the factors affecting the net costs to various industries of both steam and water power, and to give a few examples of these which have come up during the course of our own engineering practice.

The gas engine, while giving some very fine results in some industries like steel mills, where the waste gases from the furnaces are used in gas engines, will not be considered further in this paper, as it is not sufficiently in common use yet to be of especial interest to us in this section of the country.

Items in Cost of Power.

It may be said generally that the cost of producing power can be divided into two parts:

1. *Independent charges*, or the part which is independent of the output, embracing fixed charges on the plant, as interest, depreciation, insurance and taxes, and, to a certain extent, repairs.

2. *Proportional charges*, or the part which is proportional to the output, including such charges as coal, labor, supplies, etc.

Steam plants in general may be said to have low independent charges and high proportional or operating costs.

Water power plants are usually the reverse, with high fixed charge accounts and low operating costs.

Another item which should be mentioned as affecting the

cost of power is what Dr. Steinmetz calls "reliability factor," which takes into consideration the spare machinery needed to insure continuous service. The charges on this spare equipment are apt to have quite a bearing on the cost of power in a central station supplying power for public uses, where reliability must be one of the chief considerations and more spare or duplicate plant is usually maintained than in a private plant. This same factor, too, may have quite an important bearing on the value of a water power privilege.

Factor Affecting the Cost of Power.

The chief conditions which affect the cost of steam power are as follows:

1. Cost of fuel delivered to the furnaces.
2. Amount of power produced.
3. The load factor in its relation to fixed charges, whether the power is continuous and uniform, or intermittent and variable.
4. The net cost of power is reduced considerably in some concerns where the waste heat of the power plant can be used in the manufacturing processes in the form of low pressure steam or warm water.

The chief conditions which affect the cost of water power are as follows:

1. Fixed charges on the development.
2. Amount of power produced in its relation to fixed charges.
3. The load factor in its relation to efficiency of wheels, pondage and reservoir capacity.
4. The cost of supplementary power necessary to make up for the fluctuations of the water power, if required.

Variation in Cost of Steam Power.

Steam power costs the most per unit of power when produced in small amounts, and the cost is increased for fluctuating loads and when used for purposes where the load factor is small. By "load factor" we mean, in this particular instance, at least, the average output in per cent. of the full capacity of the plant. The cost of power in very small amounts has been eliminated from this paper, and it has been assumed that the plants discussed for different uses are fairly large and of about the same capacity.

Steam power costs the least per unit of power for comparatively steady continuous loads, as for paper mills and other

similar industries, and the cost may be still further reduced where there is use for exhaust steam or other by-products from the plant. Such conditions as the last are found in colored textile mills. Power costs the most in plants having a low load factor with a variable load and where there is no use for the by-products of the plant, as in a lighting or street railway plant. Between these extremes are various industries for which the cost of power will vary greatly.

Industries running ten hours a day have a low load factor comparatively, but the load while on is often fairly steady, particularly in textile mills. Public service plants usually have a load factor somewhat lower than textile mills, but the load is extremely variable, which is not nearly so favorable to economical operation as the textile load would be.

An example of the reverse of the procedure in a colored textile mill might be cited in the case of a steel mill, where the waste gases from the furnaces might be used in a steam or gas engine plant, thus making the net cost of power very low.

Power for Various Industries.

So far as we know, the net cost of steam power is the least, and the net value of water power (but not of water) also the least, for colored textile mills of any of the important industries. This is due to the usually steady load and to the fact that the waste products from the steam plant are most valuable for manufacturing purposes to those industries. If the heat required is not obtained from the waste products, it must be obtained direct from a separate boiler plant.

The net cost of steam power for textile mills gradually increases from the cost to the mill which can use all of the waste products, which will have the lowest cost, to the case of mill making white goods, where only exhaust steam for warming the buildings and drying the yarn on the slashers can be used. Next to this latter case in favor of net low cost are the industries of any nature where exhaust steam can be used only for heating. In order to give a general idea of the usual costs of power under ordinary conditions in this section of the country, an analysis of the cost of power for a station of 2 000 kw. capacity is given below. This station is similar to some which have been constructed within the last few years. Later on will be given some of the effects of by-products from the plant for manufacturing purposes.

Cost of Power for Textile and Similar Industries.

Let us first consider the cost of power under the various conditions for textile mills, and from these cases an idea of the cost to various other industries can be derived.

As electric driving is becoming so common in textile mills, we will assume for the basis of these costs that the stations considered below will be electric and of 2 000 kw. capacity, composed of two 1 000 kw. units. The costs of power from this station will usually be given as so much per kilowatt. In case it is desired to reduce this to cost per e.h.p., divide by 1.34. To get it to cost per indicated horse-power, multiply the cost per electrical horse-power by about 87 per cent., or the cost per kilowatt by about 65 per cent. It must be remembered, also, that there is no spare apparatus in these plants. This may be considered as fair average practice at present for manufacturing plants, but of course would not be tolerated for public service plants where reliability is so necessary.

In making up the cost of power here, all charges have been considered except the interest charges on the cost of land. These charges would be very variable, depending on the location of the plant. The cost of land for the station has also been omitted from the cost per kilowatt of the station. There are many opinions as to the proper percentage to charge to depreciation, interest, etc. In making up these costs, interest has been taken at 5 per cent.; depreciation, repairs on the apparatus, at 5 per cent.; and on the building at 2½ per cent.; insurance and taxes at 1 per cent.; making a total of 11 per cent. on the apparatus and 8½ per cent. on the buildings. This was for 10-hr. power. For 24-hr. power, the depreciation and repairs on apparatus was taken at 13 per cent. instead of 11 per cent. A small amount is added in both cases for incidentals.

These figures, of course, would not do for a station where the manufacture of current was the main product, as for a public service plant, because here, during a period covered by 4 per cent. depreciation, newer and more efficient types of apparatus might make it necessary to discard apparatus which was mechanically good. This course would not be so necessary in a manufacturing plant where the saving of a small percentage of the cost of power is not of such vital importance as are some other considerations.

You will note that we say "cost of power as a straight power proposition." The reason for this is that the net cost of

this power can be materially reduced by using the by-products from the plant for manufacturing purposes, as will be explained later.

Ten-Hour Power.

With a steam-engine plant, with direct connected generators, the cost of the plant per kilowatt of capacity is about $125.

The cost of power from this station, with coal at about $4.25 a long ton in the pocket, or $4.75 on the grates, would be about $33 per kilowatt per year of 3 000 hours, as for a textile mill, as a straight power proposition. This is equivalent to about $24.60 per electrical horse-power per year, and about $21.50 per indicated horse-power per year. This is equivalent to a cost of 1.10 cents per kilowatt hour.

If steam turbines are used instead of steam engines, the cost of the station will be reduced to about $105 per kilowatt capacity. The cost of power produced on steam turbines would also be reduced to about $29.50 per kilowatt year, against $33 for the engine plant. A part of this difference is made up from the reduced cost of the station and apparatus, and a part from the better economy of the turbines, which we have assumed are using superheated steam and high vacuum, which is common practice. The use of superheated steam is not common practice in engine plants, and the engine plant considered was assumed as not equipped with superheaters.

Twenty-Four Hour Power.

If steam power were to be generated for twenty-four hours a day for six days in a week, or, say, three hundred days a year, as for a paper mill or other similar industries, the cost of power would be about $57.50 per kw. per year for the engine plant and about $53 per kw. per year for the turbine plant. These costs reduce to 0.80 c. per kw. hour and .735 c. per kw. hour, respectively.

These figures should be compared with 1.10 c. per kw. hour for the engine plant and 0.983 c. for the turbine plant when producing 10-hour a day power. The difference in the cost for the two kinds of power is due to the fact that practically the same amount of fixed charges is spread over a much greater number of kilowatt hours. There is also some saving in coal per kw. hour due to the elimination of banking of fires for a large portion of the time.

Load Factors.

The power plant for the textile mill operating 10 hours a day, three hundred days a year, would have a load factor of about 40 per cent., while the plant operating 24 hours a day for three hundred days would have a load factor of about 93 per cent. These figures, of course, assume that the plants are just large enough to drive their loads. This assumption is hardly true, especially at present, when the use of electric transmission makes it easy to provide spare units. The term "load factor" as used here means the ratio of the actual kilowatt hours generated in a year to the number which would have been generated had the plant run at full load every hour in the year.

It must be remembered also that for the industrial plants under consideration the load is nearly constant throughout the operating time, which means good operating conditions.

Public Service Plants.

In a lighting plant for a city, even with the same load factor as for the 10-hour textile mill, which would be high for most of these plants, the operating conditions would not be nearly so favorable as in a textile mill, as about the same amount of banking would have to be done, and the prime movers would have to operate at variable loads. This latter undesirable feature would not be so serious in a large station as in a smaller one, so far as the efficiency is concerned, as the variation could be more nearly cared for by varying the number of units and thus operating all of them at advantageous points.

The cost of power for this type of plant is more, other things being equal, than for a plant of the same size for a textile mill having the same load factor. This is due to the effect of variable load towards a reduction in efficiency, and because of the greater cost of plant and consequently greater fixed charges per unit of output. It should be borne in mind, however, that these public service plants are usually of very large size and that their output delivered has to compete in price with the cost of power from very small stations. This would give the advantage all to the central station as far as the actual cost of making power is concerned. To the cost of making the power, the central station must add the cost of transmitting, distributing and selling it.

Plants with the same load factor can vary so widely in the

character of their loads, which would necessitate different sizes of units for different types of load, that no general figure of any value can be given for the cost of power from one of these stations.

Effect of Use of Waste Products from Power Plant for Manufacturing Purposes.

For many years it has been common practice to use the by-products, such as exhaust steam and warm water from the steam plant, for manufacturing purposes and for heating buildings, etc. It has been also common practice to take steam out of the receiver between the cylinders of a compound engine for these purposes. The saving from using the exhaust of a non-condensing engine, which would otherwise go to waste, is large, because there is no additional steam required for the engine unless the back pressure is increased. Any use of the steam is nearly all clear profit, and if all of it is used, the only part left to charge to power is the difference in B.t.u. due to the difference in pressure and the condensation in the engine cylinder, jackets, etc. The use of large non-condensing engines for producing power, except in special cases, is becoming comparatively rare, but the use of steam from the receiver of a cross-compound condensing engine for manufacturing purposes and for heating, etc., is a common practice.

It should be remarked in passing that the steam turbine at present does not lend itself to the uses of obtaining manufacturing steam under such widely varying conditions as does the steam engine. There are, as far as we know, no reliable data taken from actual operation or tests on this subject, but from some figures which have recently been made by one of the large companies, we should think that it is a subject well worth thorough investigation. There seems to be no good reason why in time the practice of bleeding turbines should not be common.

Receiver Steam.

The table given below shows the amount of coal chargeable to power when certain percentages of the steam entering the high-pressure cylinder are taken out of the receiver. This table takes into consideration the effects on the economy of the engine of not passing all of the steam into the low-pressure cylinder, cylinder condensation, etc. The percentages in the first column are the percentages of the steam passing the high-pressure cylinder which is taken out of the receiver for manufacturing

purposes. The second column is the total coal burned, and the third is the coal chargeable to power after deducting the coal chargeable to manufacturing.

Per Cent. of Exhaust Steam Used for Heating Purposes.	Lb. of Coal per i.h.p. per Hour, All Coal Charged to Power.	Net Lb. of Coal per i.h.p. per Hour after Deducting for Exhaust Steam Used.
0	1.75	1.75
25	2.06	1.50
50	2.38	1.25
75	2.69	1.00
100	3.00	0.75

If the mill did not obtain its power from steam, so that it could use the low-pressure steam of the plant for manufacturing, it would have to maintain a boiler plant of sufficient size to produce an amount of steam equivalent to that bled out of the receiver. The amount of B.t.u. or its equivalent in coal chargeable to power is represented by the amount of work done by the engine, and the losses due to the presence of the engine. The cost of generating the rest of the steam is chargeable to the manufacturing processes. By cost of generating steam is meant the total cost, including coal, labor, fixed charges and supplies of all kinds for the boiler plant. The cost in the engine room does not vary with the bleeding of steam, except possibly in some very unusual cases.

In one mill which was run wholly by water power, about 12 000 tons of coal was burned annually for dyeing, finishing, and heating the buildings. If a portion or all of this mill had been run by steam power the waste products of the steam plant would have furnished a portion of the heat required for manufacturing purposes.

The curves (Fig. 1) will give a general idea of how the bleeding of the steam from the receiver of engines would affect the cost of power from the plant given above. One curve gives the total coal used per kw. hour when steam is being bled; one, the coal per kw. hour chargeable to power, and the third curve the percentage of fixed boiler room charges properly chargeable to power. These percentages should be applied to the charges on a boiler plant complete with coal pocket of sufficient size to supply the total amount of steam, which will be larger than those in a boiler plant large enough to supply steam for power only.

By adding the cost of coal, labor and supplies to the part of fixed charges chargeable to power we get the boiler room

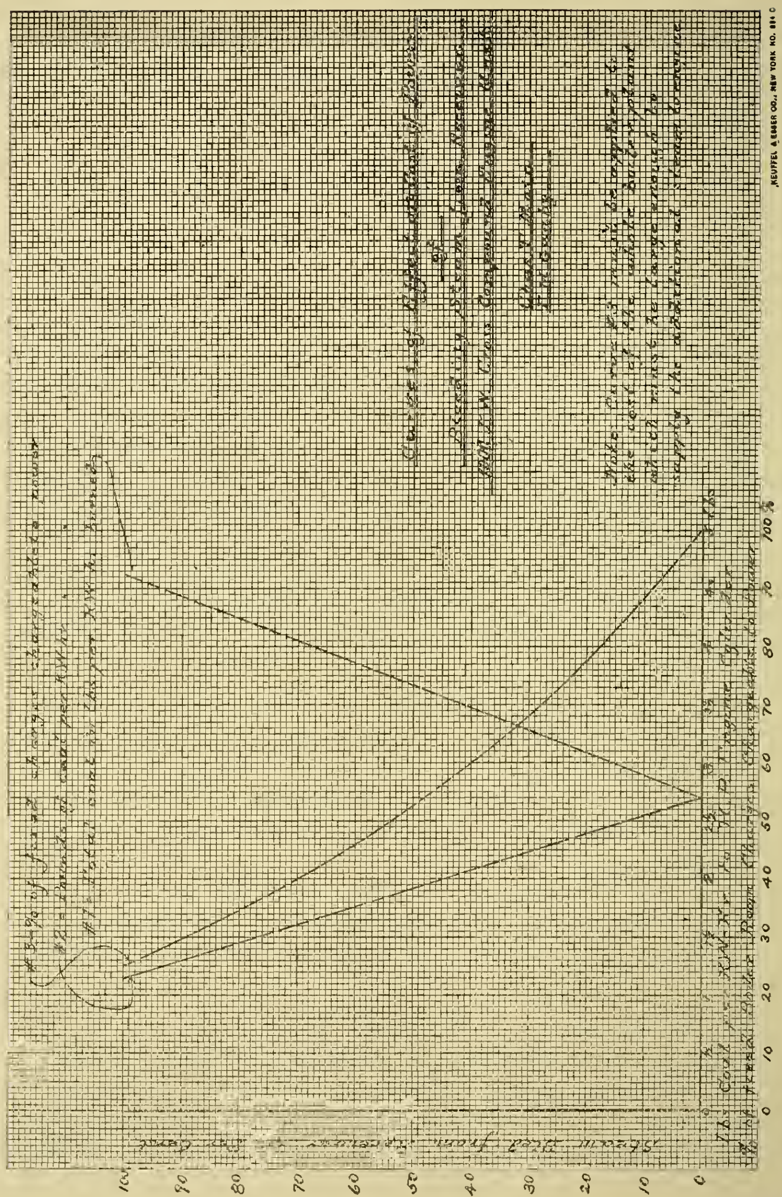


Fig. 1.

charges for power. To this should be added the total engine room charges to get the actual net cost per unit of power for the plant when steam is being bled.

Examples of Manufacturing Plants.

A few examples of the reduction in cost of power due to the uses of the by-products from a steam engine plant and the bleeding of steam from the receiver may be of interest. These are all given for textile mills as a basis. The corresponding costs for other industries can be calculated from the table and curves when the amount of steam required is known.

In one colored cotton and silk mill the power to run the mill was about 1 800 i.h.p., and for manufacturing purposes about 25 per cent. of the steam for this was required in the form of steam from the receiver. This did not include the steam for heating the building, but the cylinder ratio was such that it was deemed unwise to bleed a greater amount of steam from the receiver. Assuming the cost of power $33 per kw. with no bleeding, we get cost chargeable to power with 25 per cent. bled continuously $12.75 + $17 = $29.75. The saving, then, would be $33 — $29.75 = $3.25 per kw. year; $12.75 is the engine room charge. This was for the use of low-pressure steam alone. Probably another material saving could be made by using the overflow from the condenser for water for dyeing purposes, etc.

In another mill where much more dyeing was done, requiring a large quantity of hot water, also a large amount of exhaust steam for manufacturing and heating, the cost of power, if no steam and waste products had been used, would have been about $34 per kw. year; but when the proper credits had been allowed for items chargeable to manufacturing purposes, the cost was reduced to about $26 per kw. year, or a reduction of about $8 per kw. year.

In a plain or white goods mill where no steam would be required for manufacturing other than warming the building and slashing, the saving to be effected by using receiver steam for these purposes would be about $2 per kw. About three fifths of this, or $1.20, is for heating and the rest for slashing, so about $1.20 per kw. is the amount of the reduction which could be made in heating the buildings of an industry similar to a textile mill. The above examples represent fairly average conditions.

Several years ago in one mill there was an 800 h.p. simple, non-condensing engine exhausting into the dyehouse. If the

dyehouse was running full, the firemen in the boiler room could not tell whether this engine was running or not.

In paper mills the usual custom is to drive the paper machines with simple, non-condensing engines, the exhaust from which is used in the drying cans. The net cost of this power for coal is very small. In some mills some steam is also taken from the receiver of compound engines for other low-pressure work.

The Cost of Water Power.

The cost of water power depends upon a great variety of factors, but the essential feature is usually the fact as to whether the combined result of all these factors is such as to make the cost of the development per h.p. delivered a reasonably small amount so that the fixed charges shall not be excessive. In other words, the allowable cost of water power cannot be materially more than the net cost of producing the same amount of power for the same purpose in some other satisfactory manner, usually by steam.

There is an idea fairly common among laymen that water power is free, or at least that after the development has been completed, the cost of operation is practically nothing. This is not true because the fixed charges go on whether power is generated and sold or not. The largest item in the cost of water power is usually fixed charges. For instance, if a development should cost $125 per kw., the fixed charges alone would amount to about $12.50 per kw. per year whether the plant was operated or not.

Another idea is that if a development which is to produce 10-hour power costs about $100 per h.p. if carried to its most economical point, it will be a safe investment, but that if the cost reaches $200 per h.p. it will be well to proceed cautiously before investing in it. In general this idea is well grounded, but it should not be applied to all cases, as there are many factors affecting the cost of power, and such great differences in the market, that each case requires very careful study, and general rules are not to be relied upon.

The cost of maintaining and operating a supplementary steam plant to make up for the shortage of power during low water and floods, the effects of droughts, transmission problems in the case of electric plants, etc., must all be carefully considered as factors properly affecting the actual cost of power delivered from the hydraulic plant.

For the reason that water powers usually have high inde-

pendent charges they are more valuable for use on loads with high-load factors than with low-load factors and are hence more valuable for 24-hour power than for 10-hour power. Their value increases as the price of coal rises.

Many of the modern developments are of very large size and the cost per h.p. of the plant is in some cases small. In the determination of the cost of power, the cost per h.p. of development should not be allowed to confuse or cause misrepresentation of the actual cost of power delivered. Usually the larger the development installed, the smaller is the cost per h.p. of development, but it does not follow in all cases that the cost of delivered power will be smaller per h.p. After the engineers have made their estimates of the cost of physical structures for these developments, there must usually be added generous items for interest during construction, interest on cost before there is any return, rights-of-way, incidentals, promoting, etc. The neglect of considering items like these has caused several of the recent developments to get into disrepute.

There are usually more elements of chance and more unknown factors in a hydraulic development than in a steam plant, and these facts should be taken into consideration and properly cared for.

On the other hand, a development properly made and at a reasonable cost is a valuable asset and one which bids fair to increase in value if the price of coal increases in the future as in the past.

The prices of power where the development cost $100 and $200 per h.p. mentioned above do very well for the ordinary case in the Eastern states. There are, however, some particular uses, like mining, for instance, where there is no supply of wood, and coal is expensive, where a high cost of development is warranted, and a high price can be obtained for the power. For example, there is one development where the cost of power at some mines was from $150 to $200 a year. A hydro-electric development was made and power delivered at about $100 a h.p., thus making a great reduction in cost to the mine owners and yielding a substantial profit to the electric company.

There is a development which cost about $400 a h.p. to develop. A small portion of this power could be disposed of at the mines for $75 a h.p. with comparatively short transmission lines, but the remainder had to be carried a long distance and sold in competition with other power. The fixed charges alone on this development were about $30 to $35 a

year a h.p. and the running expenses were also high. It was impossible to produce power cheaply enough in this case to compete with other sources of powers and pay the fixed charges on the investment.

The following example is typical of many developments in New England streams with mechanical transmission of power. Compare the cost of producing 1 000 h.p. by steam and water power on an average stream at a fixed locality, where coal is $4.50 a ton delivered to boiler house, and the production of 1 000 h.p. by steam power alone at a chosen locality, where coal is $4 and $3.50 per ton delivered to boiler house.

The assumed power of the river varies in an average year so that for the driest month 490 h.p. will be produced by water, leaving 510 h.p. to be produced by steam; and for the other months in the year the water power varies so that for four months in an average year no steam power will be required at all. The average of this steam power will be about 238 h.p. for eight months per year.

In a dry year, the minimum water power will be 250 h.p. It will be necessary to run the supplementary plant for about eight months, supplying in an average year from nothing to 510 h.p. and in a dry year up to 750 h.p. In order to have such a plant run anywhere near efficiently and cost a reasonable sum, it should be of such a size as to be overloaded for a portion of the time and underloaded for the rest of the time. In this case a plant rated at 500 h.p. capable of 50 per cent. overloading would answer.

The water-power plant will cost about $75 per h.p. of development, or $75 000.

The cost of the water power will be as follows:

Fixed charges on cost of plant, interest, depreciation, insurance, taxes and repairs, say 9 per cent., $75 000 by 0.09	$6 750
Attendance and supplies	500
Cost of water power if no charge is made for water	$7 250

The cost of supplementary power is as follows:

Estimated cost of plant, 500 h.p. @ $60	$30 000
Fixed charges @ 11 per cent.	$3 300
Average deficiency of water power, 338 h.p. for eight months.	
Coal 338 h.p. by 2.10 lb. by 205 days by 10 hr. = 650 tons @ $4.50,	2 925
Attendance	1 700
Oil, waste and supplies	200
Cost of supplementary steam power	$8 125

$7 250 + $8 125 = $15 375, total yearly cost of water power and supplementary steam power.

$15 375 ÷ 1 000 = $15.38 per h.p.

Compare this with the cost of 1 000 h.p. produced by steam alone where coal is $4 per ton. This power should easily be made for $20 a year a h.p., thus leaving a margin in favor of water power of $20 — $15.38 = $4.62 a h.p. With coal at $3.50 a ton, the cost of steam power alone should be not over $18.50, with a margin in favor of water power of about $3 a h.p.

Variation in Value of Water Power.

The value of a hydro-electric power to various industries will vary in approximately the same ratio as the cost of producing power in some other way, if considered as power pure and simple, without taking into consideration other important items affecting the business, which are sometimes more vital than the cost of power itself.

To illustrate the value and cost of power under different conditions it may be well to mention the two following cases:

A price for hydro-electric power was submitted to a colored textile mill, of 1.2 c. per kilowatt hour. After due consideration, it was decided that the mill could not afford to accept the offer, the principal reasons being:

First. On account of the use of steam for manufacturing purposes and of the water of condensation for dyeing, the net cost of steam power would be less than the price of hydro-electric power.

Second. It was better for the textile company to own and control its own plant, if it had the capital to build it, which it had, than to purchase current brought over many miles of pole line, and be tied up to some foreign company.

The cost of power per kw. at the switchboard from the hydro-electric company for the operating time of the mill was about $36 per kilowatt per year; and for the steam plant which the mill was proposing to install this cost was estimated at about $34 per kw. year, but if the power had been bought from the hydro-electric company, the mill would have had to install and operate a boiler plant nearly as large as the one required for both power and manufacturing steam. It was estimated that the use of the waste products from the steam plant would reduce the net cost of the power at least $8 per kilowatt.

In another case, offers from two hydro-electric companies were made to furnish power. One offer was promptly turned down as being too high a charge. A second offer was to furnish

current at 1.2 c. per kw. hr., which is the same price which was refused for the colored mill. For a plain cotton mill, however, it was decided to be proper to accept the offer at 1.2 c. per kw. hour.

The principal reasons for accepting this offer were:

First. 1.2 c. per kw. hour = about $36 a kilowatt per year, or $27 an electric horse-power delivered. This reduced back to i.h.p. equals about $23.50 per year, which was very near the estimated cost of steam power for the quantity required, and at the price of coal for this particular industry.

Second. The mill desired to postpone the expenditure necessary for a steam plant if it could be done without serious loss.

Relative Importance of Cheap Power.

It is evident that where power is the chief product of a plant, and is sold as energy in the form of electric lighting or electric power, it is important to produce the output at the minimum price.

In most industrial plants, power is a means used to produce other product, which is sold, and it is apparent that, other things being equal, the necessity for cheap power is more important where the cost of power is a large proportion of the cost of the product, as in electro-chemical works, and the least important where the cost of power is a small per cent. of the total value of the product.

Textile mills require considerable power to run them, and the method and cost of production of this power must be kept in mind in selecting a location for a new mill and in estimating the value of an old mill already located, but it should not be allowed to play too important a part in the decision.

The chief items of cost entering into the product of a mill are materials and labor. The cost of power in a fair-sized mill should not be over 5 to 6 per cent. of the total value of the product. It is, therefore, far more important to locate in some place where operatives skilled in the particular kind of business to be carried on, or who can be trained to this work, can be obtained at reasonable wages, and where the cost of transportation of raw material and finished product is a relatively small amount, than it is to seek a location where cheap power can be obtained, but where the other items are lacking. A saving of 10 per cent. in cost of power would represent a saving of about one half of 1 per cent. of the value of the product.

The relative importance of locating a plant with reference to cheap power increases as the ratio of the cost of power to the value of the product increases. The relative importance of locating a plant with reference to the supply of help decreases as the amount of help required decreases. These factors tend to make textile mills locate with reference to good help and the paper mills with reference to cheap power. The latter use less help per horse-power than the former, and usually use the power for 24 hours per day. This causes water power to be more valuable to paper mills than to textile mills.

Standard Prices for Hydro-Electric Power.

Sometimes the question is asked, "Is there any standard price for electric power delivered?" There does not appear to be any standard, the prices varying largely according to the amount taken. For small amounts large prices can be obtained. The price, of course, must have a close relation to that at which power from a steam station would be sold. The prices for power in large amounts, as for textile mills for permanent power, seem to vary between $20 and $25 per horse-power delivered for 10-hour power, and for 24-hour power $30 to $40 per horse-power.

For surplus or secondary power which can be furnished for more than six months but less than twelve months a year, the charges cannot usually be more than at a rate of $10 to $15 a year a horse-power in large amounts for 10-hour power, or, say, about $1 a month a horse-power for such time as it is furnished, for about all that is usually saved is coal, as the fixed charges are going on all the time in the steam plant, and often a portion of the steam plant is run all the time. In a recent case it was estimated that some colored mills could afford to pay at the rate of about $15 per year for secondary power, where the power could be obtained about ten months a year. This case represents fairly average conditions, where coal costs about $4 per ton and where the power is fairly steady from day to day, so that it is not necessary to keep a full force of steam plant help.

Conclusions.

A table of the average results of the costs of power in the vicinity as outlined in this paper would be about as follows:

Typical Use of Plants.	Type of Prime Mover.	Hours per Year.	Cost per Year. Kw.	E.h.p.	I.h.p.	Cost per Kw. Hr.	Possible Reduction from Use of By-Products for Manufacturing.
						Cents.	
Textile Mill	Steam engine	3 000	$33.00	$24.60	$21.50	1.10	$1.20 to $12.00
Textile Mill	Steam turbine	3 000	29.50			.983	
Paper Mill	Steam engine	7 200	57.50	42.90	37.40	.80	1.00 to 18.00
	Steam turbine	7 200	53.00			.735	
Textile Mill	Water power	3 000	26.70 to 33.50	20.00 to 25.00		.89 to 1.12	None
Paper Mill	Water power	7 200	40.00 to 53.50	30.00 to 40.00		.55 to .75	None

Under the last column heading are given the possible reductions which may be made in the net cost of power by the use of by-products from the plant for manufacturing purposes. The extreme high saving from the engines would occur only when the engine was running non-condensing, which would be an extreme case.

The saving from the use of by-products from the turbine plants has not yet been determined. The condenser water can certainly be used, and probably quite a saving can also be made from bleeding low-pressure steam.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 1, 1910, for publication in a subsequent number of the JOURNAL.]

ANALYSIS OF WATER-POWER PROPOSITIONS.

By Edwin J. Beugler, Member Boston Society of Civil Engineers.

[Read before the Society, January 5, 1910.]

Before any projected works can be executed, it is necessary to provide funds wherewith such development may be made. Capitalists or their representatives the bankers must become interested in the project and be favorably inclined to invest in it money which may be available. To this end it is necessary for the engineer to secure full data as to the merits of the project which it is desired to develop and make a presentation of the matter in a logical and convincing manner, considering all its phases, constructive as well as financial, so as to create a favorable attitude towards the project in the mind of the financier, if the project is a good one from the investor's point of view.

The following analysis has been made with a view towards assisting in the compilation of complete engineering reports on proposed water-power developments.

The presentation may be made under the following heads:

I. General.
II. Organization.
III. Land and Water Rights.
IV. Flow of Stream.
V. Available Power.
VI. Market.
VII. Competition.
VIII. Constructive Features.
IX. Estimated Costs.
X. Earnings and Expenses.
XI. Conclusions.
XII. Appendices.

These headings may be expanded, contracted or otherwise varied to meet specific conditions and the extent of the project under consideration. No two developments are alike in even a few respects. An attempt has been made to give an analysis of form and scope rather than any particular instructions as to securing desired results, although some remarks along this line have necessarily been included in the text.

I. General.

This heading should include a concise description of the project, its location and the probable extent of the development. It may also include a statement of what the report is based upon, extent of surveys and name the sources of information.

II. Organization.

Under this heading may be outlined the plan and extent of the organization for carrying out the project. If a company has already been formed, an abstract of the charter and by-laws will be useful in presenting the case. Full copies of these papers may be given in the appendix. A list of directors and officers should be set forth and mention made of any plan of reorganization which may be contemplated.

III. Land and Water Rights.

This should cover a statement of what land and water privileges have been secured; also any restrictions or division of ownership of the property which might affect the project. The right of way for transmission lines and the matter of securing franchises should be covered.

Mention whether or not the stream is navigable or used for irrigation, and whether the state or national government has given permission for the proposed obstruction of the waterway. Also note whether locks, logways or fishways will be required.

State what, if any, existing properties, mills or other water powers and lands affected by fall and flow have been or must be acquired.

Under this heading make such recommendations as appear advisable as to the amount of land which must be secured for the project, both for an initial development and an ultimate one.

IV. Flow of Stream.

This covers the essential element of the development. The flow should be determined by daily United States Geological Survey gage records, if such record has been made for the stream under consideration. If there are no government records, then gagings taken by individuals may have to be used, or the flow may sometimes have to be estimated from records of flow elsewhere on the same stream or on adjoining watersheds. In any case, state authority for the data used. The readings should cover a period of seven years or more to be considered complete

or conclusive. The lowest daily flow and the lowest mean month's flow in second-feet (cubic feet per second) should be given, and the minimum flow should be checked by observing the proportionate run-off in second-feet for each square mile of watershed as compared with other watersheds, giving due consideration to the character of the ground, rainfall and climate.

The area of the watershed on the stream above the dam site should be stated.

The mean monthly and yearly run-off should also be checked by precipitation records, if such exist. Fairly satisfactory results as to the probable mean monthly stream flow have been obtained for eastern United States streams by the use of a method taking into account the character of watershed and a monthly evaporation factor. This is given in Appendix "A" attached to this paper. Diagrams showing the actual or estimated stream flow will present this matter more clearly than a bare statement.

The geological and topographical characteristics of the watershed should be studied to determine their effect on uniform flow, and the deductions given. Lakes and swamps regulate the stream flow more or less.

Under this head the flowage capacity of the reservoir formed by the dam, or specially constructed reservoirs at other points on the stream above the site, should be considered as to its effect upon the minimum recorded flow. The lowest recorded flow plus the flow afforded by storage will give the flow which can be reasonably counted on for primary or continuous power. The balance of the flow may be considered for use as secondary or intermittent power, remembering, however, that large reservoir capacity usually reduces and sometimes eliminates the secondary power and that a reservoir above a dam built to secure head cannot be drawn down materially without loss of power. On the other hand, an independent reservoir may be entirely emptied without affecting the head. If a reservoir or storage basin is included in the scheme, the effects of evaporation should be noted.

Data on maximum floods should be considered together with the backwater line to which the water will be raised by the construction of the dam or other obstructions in the stream, and the effect of this on other properties.

Cases are frequently found where in times of high water the tailrace level rises more rapidly than the headrace or forebay level, thereby reducing the head more or less, but, on the other hand, always giving at this time a greater amount of water.

Consider also probable future changes in stream flow or

other elements due to the diversion of water for irrigation, canalization of waterway, and any other matters which might affect the future value of the project.

V. Available Power.

This depends mainly upon two factors, viz., the flow of the river, and the head. With favorable natural features the latter may be obtained in a variety of ways, and possibly there may be a choice of several methods on one particular project. Sometimes the conditions are favorable to divert the water with a comparatively small dam and, by leading it through a canal, flume or tunnel and penstock it can be carried to a point where considerable head may be secured on account of a rapid fall of the original stream bed or on account of entering a lower adjoining valley. There are cases, at Niagara, for instance, where no dam has been required and the water simply taken from the side of the stream with the water wheels placed in a deep pit and the water carried in a tailrace to a lower point on the stream bed by a tunnel.

To obtain the amount of available power, the efficiency of the generating and transmission apparatus should be assumed at reasonable working values. A study should be made to determine the most economical head to be adopted with the given flow, so far as constructive costs are concerned, in terms of cost per installed generator horse-power. A similar study should be made to determine the head which would give the lowest operating cost per unit of power output. These studies should be made without much reference to plans previously made for the development, as there is some danger of perpetuating preliminary determinations made with insufficient data.

If the height of backwater above the dam from flood flow is limited, show what heads can be secured during low and average water condition with the limited height of dam. Note the variation of head at different stages of the stream and show by a diagram the estimated elevations of water in the head- and tail-races with various amounts of flowage for the several periods of the year.

Should the demand for power be greater than that furnished by the stream during low-water periods, auxiliary steam power may be considered for a portion or all of the time.

Sometimes the amount of steam power required is such as to make the water power an auxiliary to the steam. In this case the water-power equipment may be of quite large capacity and

more than would be warranted for the generation of primary power alone.

The use of flashboards and other devices to vary the elevation of water at headrace may be discussed and conclusions reached. As a rule flashboards are not part of the original construction, but are devised to secure some advantage which could not be foreseen until after the plant was in operation and the characteristics of load, stream flow, etc., observed.

VI. Market.

This is another essential factor in the satisfactory development of water power. Attention should first be given to the requirements of the existing market, such as mills, mines, railways and public service within transmission distance, and then to prospective industries which could use a part or all of the output. Definite elements of the market should be stated if possible, together with a list of power now used in the district to be served, and the probable future demands, probable load factors, class of present equipment and the attitude of prospective customers.

Under this heading may be considered the type of service and the form of contract best adapted to the field in question, having due consideration for the protection of both the power company and the consumer. Ambiguity or any uncertainties in contract forms are sure sources of trouble.

Contracts are generally based on a service charge for peak load plus a price per kilowatt actually furnished.

The cost of steam power, as well as the price of coal, which affects this cost to a large degree, should be determined and a study made of the advantages, if any, of the water power over the existing sources of power. Prospective industries which could use the output of the development should also be considered.

VII. Competition.

Under this head consider other water-power installations in the district, their present capacity, limitations and opportunity for increasing their output. Consider also the actual cost of generating steam power in the district or elsewhere and transmitting it to the district, as well as the possibility of generating electricity at efficient steam-power plants located at or near coal mines and the transmission of it to the market in view.

VIII. Constructive Features.

This heading should cover a description of the natural physical features at the site of the proposed development, including characteristics of the foundation bed, its suitability for dam construction, canals, power house site and the accessibility of work by railroad or highway. State what materials are available for use in construction, the general plan of development and, in case it seems desirable to present several plans, describe each one separately.

Consideration should be given to the several types of dams, such as earth, timber, rock, solid or hollow concrete, steel or some combination of these, as well as spillway requirements during flood conditions. Sometimes the construction of two dams will result in a more economical arrangement, even reckoning on the increased operating cost due to a division of equipment.

The location of the power house, possibility of trouble from ice, drift and other stream conditions peculiar to the site should be considered.

A study of water wheels and generating apparatus should be made to determine the proper types to adopt, having due consideration for the head which governs the speed within certain limits, type of governor which appears to best suit the case, the distance which the power has to be transmitted, the characteristics of current to be generated, and the construction of the transmission line. Absolute necessity for continuity of service may require a duplication of transmission lines, additional units and much more expensive apparatus than otherwise.

If the determinations are complete, the description of equipment may be detailed, but it is best to confine the description to general plans, as further study may indicate a change in minor details. The tentative size and number of water wheel and generator units should be assumed after the probable load curve has been determined, making sure on the one hand that the total 24-hr. gross power is not exceeded, and on the other hand that sufficient equipment is provided for carrying the peak load, with one or more spare units in reserve to cover repair periods. If data are lacking, make such recommendations as seem necessary to secure the missing information, such as surveys, gage readings, etc.

The character and extent of transmission lines and substations should be outlined, and if the project includes the secondary distribution of power, this should be described.

IX. Estimated Costs.

It is desirable that the estimates should cover the complete plant and all expense incident to the development. The items may be subdivided under the following headings:

Land.
Dam and Head Works.
Canals or Feeders.
Power House.
Hydraulic Equipment.
Electrical Equipment.
Transmission Line.
Substations.

Incidental expenses in addition to the foregoing subdivisions may include:

Engineering.
Interest during Construction.
Legal Expense.
Corporate Expense.
Administration.

The statement of costs should be sufficiently definite so that the scope of the construction is evident from the information given. This form of presentation gives an opportunity to see the effect of reducing or otherwise varying the costs of the several items. It is well to qualify the valuation of riparian rights on lands required for the development, stating that they are dependent on the value of the ultimate development and, on the whole, are liable to vary considerably from that shown. The cost of construction work, on the other hand, may be fairly close. A reasonable amount should be included for contingencies or unforeseen items, particularly in case rough preliminary estimates are submitted.

X. Earnings and Expenses.

This should cover the probable gross earnings for a partial initial development, or the full development, or both, as may seem advisable. The details of income should be sufficiently expanded to show how they are determined. The estimate of operating expenses should be given in more or less detail, and a presentation made of the probable net earnings, from which deductions may be made for interest on bonds, sinking fund, etc., the remainder, if any, being available for dividends on the stock.

This is the portion of the report which is most closely scrutinized by the banker or financier, for whose use the report is generally made, and it should, therefore, present the financial results in the clearest possible manner.

XI. Conclusions.

Under this heading give the essence of the project under brief paragraphs, covering the several elements and conclusions regarding them, as well as the proposition as a whole.

XII. Appendices.

This is usually a secondary part of the report and may contain such data as are supplementary or which cannot readily be put in the main body of the report without the possibility of some crowding and confusion. It may contain the following:

General Maps.

Local Maps, showing Watershed, Transmission Line and Location of Market.

Profile of Stream Bed and Flow Lines.

Diagram of Stream Flow (Natural or as Modified by Reservoir).

Diagram of Precipitation.

Table showing Available Power during Various Periods or Seasons.

List of Power Users now in District, stating Transmission Distance from Proposed Power House.

Plans of Dam, Power House, etc.

Charter of Company.

Form of Contracts.

Franchises.

Photographs of Site, Buildings of Prospective Power Users, etc.

As a rule, a preliminary office report should be made first, in which a general presentation of the project is made. Then, if further study is required or warranted, an examination of the site may be made, preceded by a study of such information as may be at hand regarding minimum stream flow, available fall, cost of land and water rights, market and competition, and, after so much investigation as is necessary, a complete report may be written.

APPENDIX A, SHEET I.

STREAM FLOW DETERMINATIONS.

Adopted from Vermeule's Method, New Jersey Geological Survey of 1894.

d_2 = Depletion of ground storage at end of month, in inches.

d_1 = Depletion of ground storage at end of previous month, in inches.

r = Monthly rainfall, in inches.

R = Aggregate " "

e = Monthly evaporation, in inches.

E = Aggregate " " "

f = Monthly flow, in inches.

F = Aggregate " " "

For each month determine f by formula $f = r - e - d$, taking e from table 1 and correcting for latitude as there indicated.

If f by this formula is less than 2" discard it and obtain correct value by one of the Curves on the Ground Flow Diagram, choosing the Curve in accordance with the character of the watershed.

In using these Curves, determine the value of $d_1 + \frac{e-r}{2}$ locate this value on vertical scale, and follow the horizontal line to the Curve, follow the vertical line there intersected to the horizontal scale, and read f

Next determine d_2 by the equation $d_2 = E + F - R$

For other latitudes correct as follows, Multiply monthly evaporation found by Table 1 by $0.05T - 1.48$ in which T is the mean annual temperature of place considered.

TABLE 1.

MONTHLY DISTRIBUTION OF EVAPORATION

Substantially correct for Latitude of New Jersey having mean temperature of 49.6 Degrees.

Month	Evaporation in inches
December	0.42 + 0.10 r
January	0.27 + 0.10 r
February	0.30 + 0.10 r
March	0.48 + 0.10 r
April	0.87 + 0.10 r
May	1.87 + 0.20 r
June	2.50 + 0.25 r
July	3.00 + 0.30 r
August	2.62 + 0.25 r
September	1.63 + 0.20 r
October	0.88 + 0.12 r
November	0.66 + 0.10 r

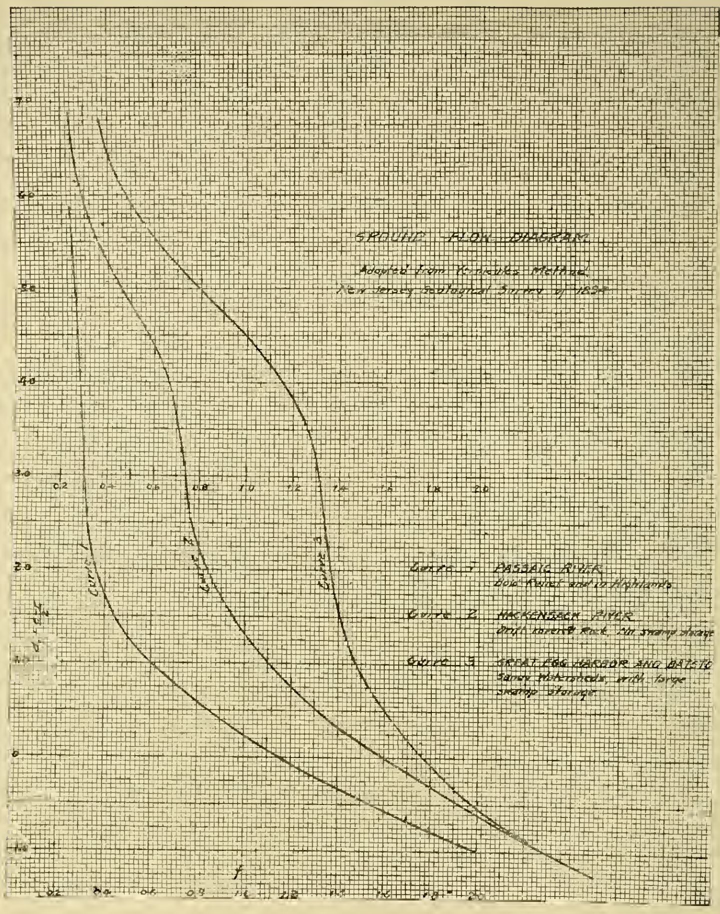
r = Precipitation in inches

EXAMPLE. Showing method of obtaining monthly and aggregate "Flow" from Wachusett Watershed, State of Mass. for the year 1897.

Month	r Mo. Rainf.	R Tot. Rainf.	e Mo. Evap.	E Tot. Evap.	f Mo. Flow Computed	F Tot. Flow Computed	d_2 E+F−R	f Mo. Flow Observed	F Tot. Flow Observed
January	3.46	3.46	.62	.62	2.84	2.84	Full	1.42	1.42
February	2.86	6.32	.59	1.21	2.27	5.11	Full	1.50	2.92
March	4.01	10.33	.88	2.09	3.13	8.24	Full	4.92	7.84
April	2.32	12.65	1.10	3.19	1.62	9.86	.40	2.82	10.66
May	5.06	17.71	2.88	6.07	1.78	11.64	Full	2.08	12.74
June	5.11	22.82	3.78	9.85	1.65	13.29	32	2.05	14.79
July	8.65	31.47	5.59	15.44	2.74	16.03	Full	2.58	17.37
August	3.47	34.94	3.49	18.93	1.15	17.18	1.17	1.60	18.97
September	1.93	36.87	.2.02	20.95	.50	17.68	1.76	.66	19.63
October	.94	37.81	.99	21.94	.38	18.06	2.19	.44	20.07
November	7.62	45.43	1.42	23.36	4.01	22.07	Full	2.21	22.28
December	6.41	51.84	1.06	24.42	5.35	27.42	Full	4.05	26.33

8-14-09-JRA.

APPENDIX A, SHEET 2.



DISCUSSION.

PRESIDENT GEORGE B. FRANCIS. — In connection with the subject of report on hydro-electric propositions it may be interesting to note the variety of arrangement of parts of the plant as suggestive of what may be selected for a case in hand.

Unless reservoirs are of large capacity a dam is built for the purpose of obtaining "head," not for storage, and a moderate amount of water which such reservoirs contain cannot be safely drawn upon without serious loss of head. Draft on such a reservoir in dry spells cannot generally be counted on. It is only when reservoirs are of very large capacity that it is safe to count upon them to tide over dry spells. Storage in long, narrow reservoirs is not as useful as otherwise, as too much loss of head

is occasioned before water from far-away parts of the reservoir is available. Storage reservoirs entirely above the elevation of the reservoir used for head are the best type of reservoirs as they can be emptied entirely without loss of head.

Sometimes a power house can best be installed at the head of falls of considerable magnitude, the wheels put in a deep pit, and the tailrace be a tunnel. Installations of this character have been made at Niagara Falls. At other times the power house can best be put at the foot of the falls and the headrace be an aqueduct or tunnel. Such is the arrangement at Montmorency Falls near Quebec.

A great many types of dams are available for different situations. They may be solid or hollow, of stone, concrete, steel, wood, earth, etc., or combinations of these materials. They should be suitable and proper for the particular conditions of each locality. They may be made straight or curved upstream. To reduce maximum depth of flood water over spillway, they may be made in the shape of teeth or a " V " or on a skew to the axis of the channel.

Headraces are often of great length; at other times very short. Sometimes they are arranged to pierce obstructions by tunnel. Once in a while they are constructed as a timber flume. They may or may not be lined with concrete to increase capacity. They may be constructed so as to require head gates and be emptied when gates are closed or to act so that they stand full when the plant is shut down.

Tailraces may be extended downstream considerable distances and made to empty below a rapid in order to increase the head. They also may be lined and by tunnel may pierce obstructions and empty by tunnels into other valleys than the original stream. Clemens Herschel, a member of this Society, has designed an auxiliary arrangement of power plant which he calls a " falls increaser," so that a greater head is obtained at times of high water than actually exists in the stream. This is done by using a part of the surplus water to obtain a vacuum beneath the wheels.

Wheels may be of a type known as either turbines or impulse wheels. Some situations can best be developed by vertical wheels, others by horizontal wheels. They may also be set below the level of tailrace water or some distance above. The back water from floods often governs the type and position. The size of units is important. The amount of installation for low water flow is also of great importance. The power obtained is often-

times divided into two parts, one of which is called primary power, which represents the power that may be obtained continually, and is substantially the low water flow of the stream, more or less governed by the amount of storage which can be obtained. Secondary power can also be obtained for delivery a part of the time, or whenever the flow of water is greater than the low water flow. This type of power is usually sold at a less rate, and sufficient extra installation is made to utilize secondary power to a greater or less extent. The amount of installation which should be installed for secondary power is one of considerable importance and depends on good judgment.

Some types of turbines are better for certain heads than others, and a careful selection is necessary in order to install the best type of wheel for the head available.

The general arrangement of all these independent parts of a hydro-electric installation is fully as important as any serious study of the operative efficiency of types of wheels.

Different types of electrical machinery for different installations should be carefully looked into. The size of units, character of transformers and type of regulators, etc., are also matters of importance.

Transmission lines may be constructed of considerable variety. They may be on wooden poles short distances apart, or steel poles long distances apart; both single and double lines should be taken into consideration.

The location of substations is another matter that requires careful attention and consideration, together with types of converters and transformers. Generally speaking, it is not practicable to erect overhead transmission lines in cities, and they must be put underground, in conduits, which are quite expensive.

It is also important that a knowledge of the market be had before completely designing a plant. The market may be for street railway or electric light or industrial purposes. In a good many instances the markets are for electro-chemical purposes.

The above will suffice to indicate what a great variety of arrangement is available in the general layout of a scheme.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 1, 1910, for publication in a subsequent number of the Journal.]

THE COAGULATING PLANT OF THE ST. LOUIS WATER WORKS.

By Arthur I. Jacobs, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 20, 1909.]

The coagulating plant of the St. Louis Water Works is situated at the low-service pumping station at the Chain of Rocks where the entire supply for the city is taken from the Mississippi River. It is about eleven miles north of the heart of the city and several miles above the nearest city sewer and the creeks draining the contiguous territory to the northwest.

The coagulating plant in its entirety consists of but two elements, the coagulant house, where the chemicals are stored and prepared for application to the water, and the settling basins, where the coagulum and sediment are deposited. This paper will treat principally with the coagulant house, a new building having been recently completed and put into service, March 21, 1909, describing its design, construction and operation.

This building and the process which it serves are unique in many respects among the large water clarifying and purification plants in the country and probably in the world There are no filters used, the process being strictly one of coagulation and sedimentation; the quantity of material used is very large; and the entire process from the unloading of the material to its application to the water is entirely automatic.

The Chain of Rocks Pumping Station was put in service in 1893. The engine house is situated about 700 ft from the river bank and gets its water through a 7-ft. tunnel in solid rock from the intake tower 1 500 ft. out in the river. This tunnel is in two sections, a river section and a shore section 32 ft. higher. The two sections are connected by an uptake shaft near the bank. From the wet well of the engine house the water is pumped under a discharge lift of about 25 ft. to the delivery well, a small chamber about 15 ft. by 47 ft. just west of the engine house. This well was connected by conduit with a series of six masonry basins situated to the south of the engine house, into which the raw water flowed and was allowed to settle. Each basin was 400 ft. by 670 ft. in area, with an average depth of water of about 15 ft. and an available capacity of 22 000 000 gal. each, or an aggregate available capacity of 132 000 000 gal. The

time of subsidence varied from 30 hr. to 60 hr. or more, depending upon the amount of water being drawn. The efficiency of this simple sedimentation varied as greatly as did the conditions governing it. Mr. E. E. Wall, assistant water commissioner, in his paper published in the Transactions of the American Society of Civil Engineers, vol. lx, 1908, states that from 10 to 80 per cent. of the sediment was deposited. It was no uncommon thing for the tap water to have a turbidity of 500–600 United States geological gage, and at times as high as 1 200.

This was the situation which confronted the administration a few months before the opening of the World's Fair. Many methods previous to this time had been suggested as a means of bettering the water supply, which I will not mention, dating back to 1866, when Mr. James Kirkwood, then chief engineer of the water works, was sent to Europe to investigate the problem of filtration with a view to applying filters here. This was the first step taken in this country looking to the use of filters as a means of water clarification. It is noteworthy to remark here that, while St. Louis was the pioneer in the work of filtration in this country, it stands to-day, almost a half century later, as the pioneer of a process, *without* filtration, as distinctive as it is successful.

The present water commissioner, Mr. Ben C. Adkins, took office in April, 1903, and the problem facing him of furnishing a purer and more esthetic-appearing water for the hosts who were to be the city's guests a year hence was no small matter. The construction of filters was out of the question on account of the short time remaining. It was finally decided to reconstruct the basins at the Chain of Rocks by cutting down the intermediate walls, making weirs of them, over which the water was to spill in a thin sheet from basin to basin and, in addition, to add alum at two of the weirs. The basins had been practically reconstructed and work had actually been started on the installation of pipes for distributing the alum solution when the attention of the commissioner was called to the use of lime and sulphate of iron, instead of alum, at Quincy, Ill., as a coagulant preliminary to filtration. While St. Louis is below the junction of the Missouri with the Mississippi and receives varying proportions of each water at different times, and while Quincy had only the Mississippi River water to contend with, still the results there were so satisfactory that experiments with lime and iron were started immediately in the water works laboratory at Bissell's Point to determine their availability. Without enter-

ing into details, it suffices to say that almost from the start it was seen that iron and lime were superior to alum for our purpose, and after three months of experiment, devices were perfected and plans drawn for a coagulant house. Ground was broken in January, 1904, and on March 21, 1904, the coagulant was first added to the water.

Exclusive of the basins which were ready at hand for almost any scheme of coagulation, the entire cost of experiment and construction of coagulant house was under $6,000, and the entire time consumed from the first day of experimenting to the day when the finished plant was put in operation was less than six months.

In substance, the process consists simply in the addition to the water of a solution of sulphate of iron and a mixture of slaked lime and water called milk or cream of lime.

The quantity of each material used during the five years from March 21, 1904, to March 21, 1909, is shown in the following table:

	Lime in Grains per Gallon.			Sulphate of Iron in Grains per Gallon.		
Year.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
1904	6.02	9.00	4.00	1.52	3.00	0.00
1905	6.28	10.00	5.00	2.20	5.00	0.50
1906	7.39	10.50	3.00	2.13	4.75	1.25
1907	6.02	9.75	4.00	2.55	4.25	0.00
1908	5.58	8.00	4.75	2.41	4.25	1.75

The average daily pumping for the above five years was 78.5 million gal., giving an average quantity of 35.1 tons of lime and 12.1 tons of iron used per day during this period.

The old coagulant house was a single story frame building 48 by 144 ft. The apparatus as originally installed was exceedingly simple, and a description of it and its operation will convey a clearer understanding of the more elaborate apparatus in the new building and at the same time give an idea of some of the many problems which confronted the department. Some of the simplest and most obvious contrivances in the new house represent the accumulated experience of five years' operation in the old house and much thought and experiment.

The old building was divided into three parts, the operating portion in the center with the lime and iron storage bins at each end. The iron bins were covered in order to keep the iron as

dry as possible. It is a question, however, as to whether this was of any value. In fact, if the iron was at all moist when received or was unloaded in damp weather, the closed bins prevented it drying out and allowed it to cake. I might mention that this has occurred in the bins of the new building, and its prevention is the one large problem we have not yet solved. It is probable, however, that the sampling of each car for moisture and the rejection of all iron showing water above a certain fixed quantity will eliminate the trouble. The lime bins. unlike the iron bins, were uncovered, except for the roof of the building. It was not thought advisable to cover them as they could not be made and kept tight, and the inevitable slaking of the lime would burst them. With the bins open, of course, the loss from slaking was considerable, as much as 15 per cent. at times. In the bins of the new building we believe we have successfully solved the problem of storing lime in large quantities. During the seven months in which these new bins have been used and which include the worst months in the year in this respect, namely, from May to September, there has been shown no loss whatever in efficiency from slaking, the samples being taken respectively from the cars during unloading and from the admission valve of the automatic scales. The samples at present, and as they have been since the inauguration of the process, are taken by the men unloading the cars, five shovelfuls being taken from each car, one at each corner and one in the center, about one foot from the surface. The samples are then crushed in a small power crusher and a small representative sample sent to the chemist. As all of our lime is bought on a CaO basis, similar to the B.t.u. basis of coal, it is highly important that a fair sample of the lime be obtained. With this end in view, we have devised an automatic sampling device for taking minute samples continuously during the entire time of unloading.

In the center of the old building or operating-room, there were originally three lime-slaking tanks and two sulphate of iron solution tanks. A fourth slaking tank was installed at a later date. These slaking tanks were of wood 6 ft. in diameter by 3 ft. deep inside. The lime was added by wheelbarrow and slaked by warm water. Each tank was equipped with a stirring apparatus consisting of a vertical shaft, with cross arm about 1 ft. from the bottom and provided with rakes. The drive was by belt from an overhead line shaft. As first built, the rakes were bars of flat steel 2 in. wide by 0.5 in. thick rigidly fixed to the cross arm. As illustrative of one of the many small things which

claimed our attention at first, I will cite that of these rakes. Soon after starting it became evident on account of frequent stoppages of the stirring device and occasional breakages of driving gears that material was wedging between the rakes and the bottom of the tank. Several types of rigidly fastened flat-spring rakes were tried, but none proved entirely successful. While the rake as finally devised was very simple and seems obviously the one that should have been used in the first place, a little consideration will show that the problem was not as simple as it would appear. The lime as added was about fist size, being broken up by hammer from the large lumps, and as soon as it was added it dropped to the bottom. On account of its size it was extremely important that it be kept constantly in motion in order that it might be entirely disintegrated before the next charge was added. Any device that would simply raise up and ride over any obstruction would not do as most of the lime would then lie on the bottom, slaking slowly into a thick mass and accumulating rapidly until it reached the cross arm. The rake had to give way to anything tending to jam under it and at the same time move everything in front of it. As finally made and used for almost five years, the rake had the form of a half circle, swinging in a vertical plane about the cross arm with an arrow head on the bottom end. A 5-lb. weight fastened to the back of the rake gave the necessary resistance to swinging and brought it back to position after raising. In the new house where crushed lime is used, the half-circle shape has been changed to a flat plate, as will be shown later.

The sulphate of iron tanks were rectangular wood boxes 4 ft. 8 in. by 5 ft. by 3 ft. deep inside. The water was brought in through the bottom through twenty $\frac{3}{8}$-in. pipe nipples closed with brass caps. Each cap had four $\frac{3}{64}$-in. horizontal holes drilled in the side, so placed that the water issuing from them made a fairly uniform sheet over the bottom. These small caps and nipples frequently stopped up, and it was no small matter to clean them out. In the new iron tanks there are four 1-in. pipes brought in through the side and connected to the supply pipes by couplings somewhat similar to air-brake couplings, so that all four pipes, if necessary, can be removed from a tank in less than half a minute.

Both the lime and iron tanks had discharge pipes near the top, and originally both lime and iron were discharged directly into the uptake shaft through wrought-iron pipes, the iron pipe being some 15 ft. longer than the lime pipe in order to introduce

the iron to the water before the lime. After a few weeks' operation, the decreased output of the pumps led to the valve chambers being examined, and it was found that the valves were badly covered with hydrate of lime. The coating was so hard that it could not be touched by strong muriatic acid and it was scraped off with difficulty. Fortunately, we had on hand a 4-in. centrifugal pump direct connected to a 500-volt-motor and this was immediately installed; also, 1 000 ft. of 3-in. cast-iron pipe was laid in order to pump the lime into the delivery well beyond the main pumps. Scarcely a month had elapsed after we had begun to pump the lime than the 3-in. pipe had a deposit about an inch thick, leaving a hole in the center 1 in. in diameter. A 6-in. cast-iron pipe was then laid and the expedient tried of cooling the hot lime before pumping. This proved successful and we had no further trouble. After nearly five years' operation the 6-in. pipe was recently broken into and found to have a coating of an average thickness of only $\frac{1}{8}$ in. and nowhere thicker than $\frac{1}{4}$ in.

As mentioned previously, warm water was used to slake the lime. The temperature of this water necessary for continuous slaking in the size tanks installed, as determined by laboratory tests, was about 120 degrees fahr., and for about three years after starting this temperature was maintained.

The amount of water added was fixed at 30 gals. per minute per tank, irrespective of the amount of lime added, which latter, however, we aimed to limit to 30 lb. per minute per tank. This gave a maximum strength of milk of lime of $8\frac{1}{3}$ lb. of water per pound of lime, or 7 000 gr. per gallon. A saturated solution of lime water contains about 68 gr. per gallon at 60 degrees fahr., or less than 1-100 of the strength of the milk of lime in our tanks. This will give some idea of the size of the tanks necessary had we made lime water instead of milk of lime as had always been done before in water-clarifying processes. With this manner of working, the resulting temperature of the milk of lime varied between 140 degrees and 160 degrees fahr., the higher temperature being reached when the maximum amount of lime was added. Almost from the first it was seen that it required much more lime per gallon to coagulate the water in the basins than it did to get the same coagulation in a battery jar in the laboratory, using lime water, and tests of the milk of lime from the tanks showed that we were obtaining an efficiency in the slaking process of less than 85 per cent.

After some three years' operation, and as the result of experiment in the laboratory, it was discovered that if the tempera-

ture of the slaked lime was raised to about 200 degrees fahr. there was obtained a gain in efficiency, according to our chemist, Mr. Wilson F. Monfort, of about 15 per cent., or practically perfect hydration. This not only conduced to greater economy in the use of lime, but led to other economies as well. The water used for slaking was the cooling water from a surface condenser in the engine house taking the exhaust from auxiliaries around the plant, and was pumped by the circulating pump to the coagulant house, a distance of about 650 ft., through a 4-in. wrought-iron pipe. As this water, even during the summer, was never hot enough for our purpose, it was always necessary to raise its temperature by the addition of live steam. And it was no easy matter to keep the temperature constant, as the temperature of the cooling water varied with the number of auxiliaries exhausting into the condenser and the quantity varied with the number of slaking tanks in use. A temperature regulator was tried, but did not prove successful. In order to obtain the temperature of 200 degrees fahr. in the tank it became necessary to increase the temperature of the feed water to about 160 degrees fahr., and this, in turn, called for about twice as much steam as had been used previously and did not lessen the difficulty of regulating the temperature. It has been estimated that the steam at this time cost us about $4 000 per year, figuring cost of coal only. While, of course, the added cost for steam was much more than counterbalanced by the increased efficiency of the slaking process, any reduction in the temperature of the feed water (still keeping the temperature in the tanks at 200 degrees) would be a distinct saving. The consideration of this feature led to our present distinctive method of continuous and efficient slaking of lime.

Instead of adding, as formerly, $8\frac{1}{3}$ times as much water as lime, the amount of water added was cut to about $3\frac{1}{4}$ to 1, the latter proportion making as thick a batter as could be properly handled. Having only about 40 per cent. as much water as before to heat to 200 degrees in the tank, the initial temperature of the feed water could be reduced to about 110 degrees The high temperature of the slaked lime and the comparatively low temperature of feed water led immediately to the suggestion of having the slaked lime after leaving the tanks, and before being pumped, heat the feed water and thus do away entirely with the hot water supply from the engine house. This scheme had another advantage, inasmuch as it would reduce the temperature of the slaked lime and consequently the amount of cold water necessary to add to it before pumping.

To this end a steel heater tank was built 4 ft. 6 in. diameter by 3 ft. 3 in. deep, containing 1½-in. copper pipe coils and stirring apparatus. The copper coils had just previously been taken from the reheaters of the pumps at Bissell's Point and their diameters determined the diameter of the tank. All the slaking tanks discharged freely into the top of this tank, which, in turn, discharged through an overflow pipe near the top into the pump box where, after dilution with cold water, it was pumped to the delivery well.

Unlike the former method of slaking, when the quantity of feed water was never changed, it became necessary in this later scheme to accurately apportion the water to the amount of lime being slaked. For this purpose a constant head tank was installed in the lantern about 10 ft. above the tanks, a float valve keeping the level of water constant. This float valve received water from the high-pressure mains, through the coils of the heater tank. The discharge was through a 2-in. downtake pipe branching at its lower end into four 1½-in. pipes, one to each tank. At the end of each branch pipe there was placed an adjustable orifice of our own design by which the quantity of water entering the tank was regulated. This orifice was in effect a needle valve and consisted of a thin steel plate having a ¾-in. round hole through which an accurately made cone 2 in. long was made to move by means of a micrometer screw. They were calibrated by setting the screw at different readings on the scale and recording by means of a stop watch the time it took the water to rise between two hooks set in the side of the slaking tanks. From this data a plat was made showing pounds of water per minute for any setting of the screw, and for the use of the men a table was prepared showing the setting of the orifice for every pound difference in weight of lime added. These orifices proved to be very accurate in the discharge of water.

In the new house the orifices, while similar in principle to those just described, are all combined in one casing and so interconnected that one setting adjusts all three orifices, so that tanks may be changed without paying any attention whatever to the orifice setting.

The method just described of thickening the batch and using the heat of the lime effluent to heat the feed water justified our expectations from the first and has, with the exception of minor interruptions, been in successful use for over two years. The interruptions I speak of were in the old house and were due to the unavoidably small slopes of the effluent pipes from the

lime tanks, causing them to stop up and also to the fact that the coils in the heater tank extended to the bottom, and the sand and unburned rock, etc., settling to the bottom and thrown against the coils, wore them out and required repairs from time to time. These defects, as will be shown, have been eliminated in the new house.

New Coagulant House.

The new building is situated just west of the old building about 85 ft. from the river bank and about 575 ft. from the pumping station. It is designed to handle coagulant for an average daily pumping of 160 000 000 gal. and a maximum pumpage of 240 000 000 gal. The average daily pumping for the last year, from November 1, 1908, to November 1, 1909, was 85.3 million gal. with a maximum of 118.2 million gal. The building above the ground level is divided into three sections, the storage bins comprising the two end sections, with the operating section between them. A basement below the ground level extends the full length and breadth of the building. On account of the treacherous nature of the soil, being quicksand and river silt, and being so near the river bank, and also on account of the heavy loading due to the storage bins, it was decided to go to bed rock for the foundations. These foundations are twenty-two concrete piers placed in groups of nine each under each set of four bins and a group of four in the center of the building. These piers vary in depth from 16 to 25 ft. including the caps. The specifications called for the piers whose diameter varied from 3 ft. 6 in. to 7 ft. to be sunk to rock and enclosed by steel shells for their entire depth, but at the contractor's request he was allowed to excavate and brace a trench 8 to 10 ft. deep, at which depth water was encountered, before starting the steel tube. These trenches were square in section and one foot larger on sides than the diameter of the circular pier, making the piers much heavier than called for.

In the design of the substructure supporting the storage bins these conditions had to be met:

1. Sufficient head room below the bins for the installation of the lime and iron crushers.

2. Necessary space for the crushers and conveying machinery and as few obstructions, such as columns or walls, as possible in order that the conveying machinery could be gotten at conveniently for cleaning and repairs, but principally to afford plenty of room for the hand handling of materials in wheel-

barrows in case of a serious shutdown of the reclaim conveying system.

3. To admit of starting the circular form of the bins on the exterior of the building at the ground level, for architectural considerations.

As built the basement is of rectangular shape 120 by 40 ft. with 8-ft. head room and with comparatively few columns and those so placed as to afford plenty of room for all purposes.

Of the nine piers supporting the bins, the three across the end of the building *A C A* were brought up to the elevation of the basement floor (105). The other six are 9 ft. lower (96). The elevation at these latter piers was raised to 105 by two transverse beams 9 ft. deep by 3 ft. wide and resting on piers *B D B* and *B E B* respectively. Across the structure so formed at elevation 105 were built the wall beams, enclosing the basement, and the columns in the basement, bringing the structure to elevation 113. The double columns over piers *D* and *E* were made necessary to accommodate the reclaim conveyors which pass between them. Above 113, and resting on the wall beams and columns, is a combination of circular and straight beams. These beams are of monolithic construction, being built their full depth of 8 ft. in one operation, i. e., without cessation of work. The straight beams were employed, of course, to support the circular beams instead of resorting to additional columns. The conical bottoms of the bins hang inside the circular beams and are tied to them by steel bars. The specifications called for these bottoms to be built integral with the circular beams, but in actual construction this requirement was waived and the bottoms built as one piece after the beams were poured, the contractor being required by the department to supply additional steel to tie the bottoms to the beams.

It will be noted that all these beams are very deep (8 ft.–9 ft.) and comparatively short, requiring considerable steel for taking the horizontal shear. The tension bars were figured by the straight line formula, but it is very probable that for beams as deep and short as these any beam formula gives an excess of steel. However, it was not thought advisable to try to economize on these beams in view of their importance in the building and the comparatively small saving which might have been effected. The radial bars in the conical bottom were designed to take the vertical load due to the weight of material in the bin, assuming no friction on the sides of the bin, and also the distorting strains due to the eccentricity of the apex of

the cone with respect to the base. The circular bars take the bursting strains.

The vertical walls of the bins start at elevation 121. The diameter of the bins is 20 ft. inside, and the straight sides average about 37 ft. inside. The walls are of reinforced concrete 8 in. thick; the horizontal circular bars are in two pieces with joints lapping forty times the smallest diameter of the bar. The pouring of the concrete alternated from one group of bins to the other, each group of four bins being raised 3 ft. at a time in one operation. An elevator in the central section of the building with a hopper near the top and chutes leading from it distributed the concrete to any part of the building required. The exterior of the bins is faced with brick, held to the concrete by metal wall ties one for every brick every fourth course. All walls of the central section are of brick, with the exception of a small portion of the north and south walls (from 114–121) which is of concrete.

The iron and lime bins are identical with one exception. While the iron bins are covered only by the roof, the lime bins have an additional roof in the shape of a cone whose apex is at the side of the bin on the longitudinal center line of the building and at the point of admission of lime into the bin. It is made of $\frac{1}{8}$-in. steel plates riveted to 6-in. channel beams placed radially around the cone whose angle with the horizontal is always greater than the angle of repose of the lime, assuring the minimum of air in the bin when filled.

There are two manholes into each bin, one at the top through the lantern floor and another on the side about 12 ft. below the top. There are also several bar holes 6 in. square and closed with doors along the full length of each bin, in order that the contents of the bins might be gotten at with bars in order to loosen them in case of caking or arching. There are also several 2-in. pipe set in the cone bottom and closed with plugs for this same purpose. As mentioned before, the iron has caked considerably and these bar holes have been of great service. The lime does not cake at all and arches only infrequently just over the point of discharge in the bottom.

The capacity of these bins is approximately 10 800 cu. ft. each, giving a total storage capacity of about 1 250 tons of lime and 1 600 tons of iron. At our present rate of use, this gives thirty-seven days' storage of lime and one hundred and fifteen days' storage of iron, amply sufficient time to tide us over any unusual delay in the shipment of materials.

The architect, Mr. J. J. Roth, who is responsible for the very pleasing exterior, describes its architectural features as follows:

"The requirements of the coagulant house were unusual, and the purpose for which the building was to be used practically fixed the shape and proportion of the plan. In consequence, the fixed conditions were rather awkward to overcome in order to produce an architectural effect. Thus it was decided, as essential, to emphasize the utilitarian purpose of the building in the architectural lines of the façade. In the end wings where the storage bins are located, the plan neither permits of nor calls for fenestration as an architectural feature. Naturally, it was desirable to obtain some recompense in featuring, this being obtained by the use of large simple wall surfaces and terminating the composition with a central motif where all the interest and ornament are centered. This central or entrance motif consists of two massive pylons supporting a low pediment, the space between being filled in with a large circular headed window. This large window clearly indicates an immense room for working space, requiring as much light as it is possible to obtain. Thus practical needs were not sacrificed in an eagerness to produce an effect.

"The entire building is crowned with a pseudo-Doric entablature. The members of the cornice are simple with heavy modillions and deeply undercut egg and dart ornament to retain the general scale. The type of ornament generally employed is strictly architectural, with a touch of Grecian influence, and, while lacking in the softness and roundness of this style, it is, nevertheless, eminently suited to this work. The base course of the building is of concrete with a superposed band of brickwork of heavy pavers with a belt course of terra cotta above to tie in the end wings of building to the central pavilion."

With the exception of the base course, all ornamentation is of terra cotta. The brickwork above the belt course is laid up in brick of three different shades from deep red to black, in garden-wall bond with $\frac{3}{4}$-in. joints.

Above the basement, the central or operating section of the building has two floors, one at the ground level, called the pump-room floor and a second or mixing-room floor. There is in addition a lantern at the top of the building which crosses the mixing room and partly covers the bins on each side.

In the basement are the crushers for both lime and iron, most of the conveyors for storage and reclaim, air compressor, sump pit and pump and system of piping. On the pump-room floor are the heater tanks, pump-box and pumps, switchboard and wash and locker room. On the mixing floor are the tanks for slaking lime and making the sulphate of iron solution, with

the auxiliary storage tanks and weighing and measuring devices. On each side of the building there is a track for the reception of cars, the east track being for lime and the west track for iron.

The description of the conveying and elevating system for handling the lime, both storage and reclaim, will suffice at the same time for the iron-handling system, which is similar to the lime system in all but one respect, which will be noted later. The unloading points for lime are two in number, one at each end of the building on the east or river side. They were placed as far apart as possible in order to provide the required track room for the movement of cars. The chutes at these points are built in two sections, the outer or fixed section extending from the opening in the wall to the crushers, while the inner or movable section extends to the car door when lime is being unloaded. This inner section is about 5 ft. 6 in. long and for half its length its width is uniform, about 2 ft. (with sides 12 in. high). For its remaining length the bottom is fan shaped, flaring out to a width of 4 ft. at the car door. This fan-shaped end is so hinged that when not in use it is folded up and the entire movable section slid into the fixed section and out of sight. The opening in the wall is closed by two malleable iron swinging doors, conforming in shape to the contour of the base course.

At each unloading point there is a No. 2 Sturtevant crusher having a capacity of about 15 tons per hour, into which the lime from the cars is conveyed by the chutes just described. These crushers take the lime, which varies in size from a fine dust to 15-lb. lumps, and crush it to ½-in. diameter and smaller. Directly under each crusher, and running along the east wall of the basement, are two belt conveyors. These two conveyors are run at a slope of about 1 in 10, being set in pits below the basement floor at the crushers and rising to their common point of discharge near the center of the east wall to above a third or cross conveyor which carries the lime to the elevator for elevation to the tops of the lime storage bins.

In the lantern, and running over the tops of the bins in the center line of the building, is a scraper conveyor taking the discharge from the elevator and distributing it to the bins. The discharge into the bins is through short steel chutes bolted to the bottom of the conveyor casing and closed by sliding gates operated by lever handles. This type of conveyor was chosen because of the protection it gave against choking of the conveyor and elevator in case the bin being fed into filled up before the machinery could be shut down. In practice there is

always one extra chute left open beyond the one into which material is being delivered, usually the last chute, and its bin is never allowed to fill up completely.

In reclaiming, the lime is taken from the bottom of the bin through a 15-in. round steel chute and fed into a belt conveyor. A screw conveyor set horizontally on the basement floor is interposed between the chute and the conveyor and serves to regulate the flow of material on to the belt. From the belt the lime is delivered to an elevator adjacent to the storage elevator and, as in storing, is again carried to the lantern, this time being discharged directly into an auxiliary storage tank, or daily supply hopper, as we call it, set on columns in the mixing room above the slaking tanks.

The object of the daily supply hopper is to provide at all times a storage of between 25 and 30 tons of material to insure continuous operation in case of a breakdown of the reclaim machinery. As a further precaution there is connected to the 15-in. chute below the bins a 6-in. screw conveyor set horizontally and operated by a hand crank. In case of emergency, after the supply in the daily supply hopper has run out, small platform scales may be run under the 6-in. screw on which wheelbarrows will be run and the material taken directly from the bins, weighed and carried to the tanks. An Otis electric freight elevator of 1 600 lb. capacity is provided to carry the wheelbarrows between the basement and mixing room.

Each crusher with its side conveyor is driven by its own motor of 30 h.p., the motor being placed at the crusher and driving the head shaft of the conveyor through a line of shafting along the wall. The cross conveyor drive, on the other hand, presented some difficulties. It must run with either crusher motor separately or the two motors running together, not improbably at considerable differences of speed. In order to prevent choking it must be started before or at least at the same time as the side conveyor and yet could not be directly connected to the side conveyors because of the different speeds of the motors and because if one motor only was to be run, its motion would be communicated to the other motor and side conveyor. There are several methods, including a separate motor for the cross conveyor, which could be used, some objectionable, all more or less complicated. This problem was happily solved by the design of an ingenious automatic clutch of the silent pawl-and-ratchet type, as follows: On each end of the head shaft of the cross conveyor there is mounted one of these clutches, the

ratchet being fixed to the shaft, while the part carrying the pawl is loose. The latter is connected by chain to a counter-shaft, which in turn is driven by its respective line shaft from the motor. Not the least advantage of this device is that it requires no attention at all from the operator. It is the design of the R. H. Beaumont Company of Philadelphia, who built and erected the conveying machinery. The storage elevator and the scraper conveyor are driven by a single motor of $7\frac{1}{2}$ h.p. in the lantern; the reclaim system, consisting of conveyor and elevator, is driven by a single $7\frac{1}{2}$ h.p. motor, also in the lantern. The motor drives the elevator, which in turn drives the conveyor in the basement. The iron conveying system differs from that just described in having but one point for unloading, at the south end of the building on the west side, and, therefore, requires but one side conveyor and dispenses with the automatic clutch. The crusher for the iron is a No. 1 Williams hammer crusher driven by a 15 h.p. motor. There is also an automatic power shovel at this point for unloading the iron from the cars.

With the exception of the scraper conveyors in the lantern, all conveyors are 16-in. four-ply rubber belts of the Robbins type. The scraper conveyors have double "Ley" chains and metalline bushed roller carriers. The flights are of $\frac{1}{4}$-in. steel 6 in. by 24 in. spaced 2 ft. apart. All elevators are of the centrifugal discharge type, single chain, with 16-in. by 6-in. malleable iron buckets spaced 2 ft. apart. To keep down the dust, all conveyors and elevators except the reclaim conveyors are enclosed in riveted steel casings of No. 12 gage steel with angle iron stiffeners in the corners. The tops are bolted on to permit of removal, Doors are provided at convenient points on the top and sides to allow for easy inspection and for cleaning. The reclaim conveyors run in pits below the basement floor, which are now covered by wood, but will be later covered by pressed steel plates.

The maximum quantities to be handled by these conveyors were fixed as follows: Line storage, 30 tons per hour; iron storage, 15 tons per hour; iron and lime reclaim, 6 tons per hour. But all apparatus of the same type was made the same size, making all parts of the same type interchangeable, reducing the number of spare parts and minimizing the liability of a prolonged shutdown.

The lime-slaking tanks are three in number on the north side of the mixing-room floor. They are of $\frac{3}{8}$-in. steel, 7 ft. 6 in. in diam. by 3 ft. 6 in. deep and have two hinged covers of $\frac{1}{8}$-in.

steel stiffened with angle irons. They are set with their bottoms 18 in. below the floor, so as to bring the top within reach of wheelbarrows in case the latter are needed, due to a serious breakdown of the conveyors. Across the top of each tank are two 6-in. channels 8 in. back to back with a $\frac{1}{4}$-in. coverplate above them. To this plate are hinged the two movable covers and through it is brought the discharge chute from the scales above and the feed water pipe. One of the two large covers has a small door which allows for inspections and taking temperatures. The stirring apparatus follows in outline that of the old tanks, with such changes in rakes as have been noted previously, and is much more ruggedly built. The driving of the stirring apparatus is from below the tank, and this was done for two reasons: first, to keep the space above the tanks as free as possible, for obvious reasons; and, secondly, to allow the use of one line shaft to drive all the tanks, including the heater tanks on the floor below. The vertical shaft from the bevel gear drive below was brought through the bottom of the tank in a long bearing without the use of the usual packing gland, by enclosing it in a heavy hollow casting bolted to the bottom and terminating in a steel pipe rising several inches above the level of the lime. Above the pipe and keyed to the shaft is a cast-steel hood enclosing the pipe in its turn, and to the bottom of which is fixed the cross arm. The weight of the shaft and its attachments is taken by a roller-thrust bearing in the bottom of the tank inside the casting. A vertical bearing at the top of the steel shaft was set between the two 6-in. channels simply as a measure of precaution to hold the alignment, as all parts were designed heavy enough to dispense with it. These tanks are designed to slake a maximum of 80 lb. of lime per minute, but 90 lb. per minute may readily be slaked in them.

Above the slaking tanks, and between the four columns supporting the daily supply hopper, there is a platform on which are set the three automatic scales, which weigh out and discharge into the tank the proper amount of lime in a given time. These scales were made to our specifications by the Richardson Scale Company and are dumped by an electrical device operated by a clock and were, to our knowledge, the first scales ever built with this feature. Its operation is as follows: When the bucket has been filled with its proper weight of lime and the admission gate has closed, the rod connected to the discharge gate is held fixed by a system of levers arranged as a toggle with its three points in line and holds the load in the bucket.

The plunger of a solenoid, energized through a relay, operated by the clock at the proper time, breaks the three-point alignment and permits the scale to dump. The current for the solenoid is obtained from one of a duplicate set of motor-generators of 450 watt capacity, one of the motors taking current from the 500 volt direct current line, the other from the 110 volt alternating current line, and both generators deliver a 30 volt direct current. The scales weigh from 40 to 100 lb. by $\frac{1}{4}$-lb. increments and may be dumped once in 1, 2 or 4 min. With this combination of weight and time interval any weight between 10 and 100 lb. per minute may be discharged into the tank.

The supply to each scale is through an individual 8-in. spiral riveted pipe fixed to the bottom of the daily supply hopper and closed by a flat gate.

The daily supply hoppers, one for the lime and one for the iron, are circular steel tanks of $\frac{1}{4}$-in. metal, 10 ft. diameter and 14 ft. 6 in. over all, and holding about 60 000 lb. of lime and 70 000 lb. of iron. They provide an average of approximately 20 hr. supply of lime and 70 hr. supply of iron, against a possible breakdown of the reclaim system as explained before. In order that this may be so, it is necessary to have the tanks continually kept filled to a given point and never permitted to get lower. The device by which this is done finds its prototype in the float switch which keeps the level of water in a tank between two fixed points. In our case the difference between points represents about 10 000 lb. of material. This is accomplished by means of a very simple and clever device suggested by one of our men. A flat paddle of $\frac{1}{2}$-in. oak, 32 in. long by 12 in. high, is suspended in the tank by a rod turning in a bearing on the top of the tank. The paddle is set with long side horizontal, and when the material is below the paddle its face is vertical. In this position circuit is made by a switch with the starting side of an automatic motor starter which puts the reclaim system into motion and begins filling the tank. The paddle is so set that as the cone of fresh material rises it presses the paddle out of the vertical but cannot fill in behind it. As the material rises the paddle is thrown farther and farther out of the vertical until the tank is practically full, when circuit is made with the stopping side of the starter and the supply is shut off.

From the slaking tanks the lime flows directly to the heater tanks, of which there are two, through 6-in. vertical overflow pipes. These pipes discharge into a collecting hopper, below

which is a swinging chute device which diverts the stream of lime through a "Y"-shaped casting into either one of the two heaters. The heater tanks are of steel, 5 ft. diameter by 5 ft. 3 in. deep, with sides $\frac{1}{4}$ in. thick and bottom $\frac{3}{8}$ in. thick, and with covers similar to those of the slaking tanks, though not hinged. In each tank there are two rings of $1\frac{3}{4}$ in. copper coils, each ring having ten convolutions and all hung from the top of the tank, leaving a clear space 6 in. high over the whole bottom. This space is sufficient to prevent cutting of the lower coils by sand, etc., which is shown by the thin coating of hydrate of lime on them after a run, which is usually of a month's duration. The lime is kept in motion by paddles on a vertical shaft. The drive for this shaft is from the top, and ball-thrust bearings at the top take the weight of shaft and paddles. The aligning bearing at the bottom is a 2-in. pin fixed to the bottom, over which fits a socket keyed to the shaft. A $\frac{1}{4}$-in. hole through the pin connected to a $\frac{1}{8}$-in. water pipe supplies a stream of cold water to the top of the pin and which in flowing around the bearing into the tank keeps out the sand and prevents cutting. A vertical steel trough in front of the discharge, riveted to the side and reaching to within 5 in. of the bottom, compels the lime to travel the full depth of the tank before leaving. The discharge openings of both tanks are connected together by a "Y"-shaped casting, the leg of which discharges into the pump box. In this casting is a flapper valve, which in normal operation, i. e., when the lime is flowing to the pump box, lies flush with the bottom and closes a 6-in. outlet below it. When required, this flap may be raised, stopping the flow to the box and diverting it to the outlet, from whence it flows downward through a 6-in. vertical pipe to a 6-in. steel-cased well connecting with the inshore tunnel. There is also a short 6-in. connection from the overflow of the pump box to this pipe, so that in case of failure of the pump, the lime will rise in the box and overflow into the tunnel.

The pump box is a wooden box 3 ft. wide by 5 ft. $10\frac{1}{2}$ in. long by 3 ft. deep, with a motor-driven pump on each of the long sides. Only one pump at a time is used, the other being held in reserve. The object of the box is primarily to furnish a continuous supply of liquid to the pump irrespective of the varying speed of the motor and the amount of milk of lime brought to the box.

The conditions to be met by this box are varied, as follows:

1. Both pumps must be self-priming.

2. There must be as few valves as possible, and those of the simplest kind.

3. The idle pump must either be empty or filled with clear water.

4. In case the running pump fails for any reason the lime must discharge into the tunnel and the idle pump must still be kept clear of lime.

5. Cooling water must be added under all conditions.

All of these conditions have been met successfully and in a very simple manner as follows: The box is divided into two chambers by a transverse partition. The chamber nearest the heater tank is in turn divided into three smaller compartments by two lengthwise partitions which have a groove at the bottom 8 in. long by $\frac{1}{8}$ in. high. In the center compartment and 8 in. from the top is the overflow pipe mentioned above. In the transverse partition, and opposite the two outside compartments, there are 6-in. openings which are closed by loosely fitting slides. The two slides are fixed to an arm pivoted in the center and operated by a lever at the top of the box and so set that when one opening is closed the other is open. This is the nearest approach to a valve we have made use of. Returning again to the three compartments, the lime is discharged into the center one, while the suction of the pumps is in the outer two. To illustrate the working of the box, let us assume that the right-hand pump is running. The slide lever has been thrown to the right, closing the right 6-in. opening and opening the left one. The cold water entering the undivided chamber, and kept at a constant head 2 in. below the overflow by a float valve, passes through the 6-in. opening on the left, through the small groove under the partition, where it mixes with the lime, and passes under the second partition to the outer right compartment, where it is taken up by the pump. It will be seen that because of the smallness of the grooves under the compartment partitions, there is a considerable difference in elevation between the left and center compartment, assuring clear water in the former compartment and, therefore, in the idle pump, and of sufficient elevation to insure its being primed. This fulfills the first three conditions. Should the pump stop, the lime would rise in its compartment and in the right compartment until it overflowed and raised with it the water in the left compartment and float chamber. As this float does not close completely until the water rises above the overflow, there is always a flow of clear water towards the center compartment. There is a

second float in the float chamber, which operates contrary to the first, remaining shut when the water is at normal elevation and opening when it reaches the overflow level. This fulfills the remaining two conditions. To change pumps it is only required to throw the lever from left to right. This description of the box and its operation may seem somewhat involved, but in practice it works perfectly, the only attention required being to occasionally clean the sides of the center compartment of incrusting lime.

From the pump box the lime is pumped to the south end of the delivery well, a distance of nearly 900 ft., through either one of two 6-in. pipes. The lime mixture drops directly into the water from the pipe without any intervening distributing device, the violent turmoil of the water in this well being deemed sufficient to insure thorough mixing. The pumps are 2½ in. centrifugal, driven by a 15 h.p. 500-volt variable speed interpole motor. The speed of the motor determines the amount of cooling water added, and as the temperature of the diluted milk of lime is aimed to be kept at not over 100 degrees fahr., the speed is adjusted accordingly.

While there are two pumps and two pipe lines it was thought advisable to interconnect them, so that either pump could discharge through either pipe. To do this in the ordinary way would have required five valves and several drain valves. Besides, there is no commercial valve that we know of that will not coat in time and leak. This was accomplished by a single plug valve, the plug being 8 in. in diameter and 15 in. long and has five 3-in. ports. The plug and barrel are slightly tapered for adjustment and a ⅛-in. pipe tapped into the barrel forces water between their surfaces and into the ports and prevents the lime from coating them. After several months' run the surfaces of the plug and barrel are as clean as the day the valve was installed. The valve sets horizontally between the two pipes just below the basement ceiling and is hung by straps to permit of temperature movements of the pipes. It is operated from the floor above through bevel gears, and there is a dial under the hand wheel indicating the position of the ports. This valve has the added advantage that when the setting is changed from one pipe to the other the pipe put out of service drains automatically. It is well to note in passing that in order to successfully handle thick mixtures of milk of lime it is essential that all pipes be of ample section, straight, with large slope, and openings so placed as to admit of ready inspection and easy cleaning. The fewer the

valves used the better, and these should be simple and easily cleaned.

The feed water system has been explained before. The head tank is a steel box with wood covering and is placed above the daily supply hopper for lime. It is divided into two parts by a transverse screen, with the entering water (kept at a constant head by a float valve) on one side and the discharge on the other. The discharge is through a single vertical $2\frac{1}{2}$-in. pipe leading from the bottom of the tank to the adjustable orifices, 4 ft. above the scale platform, giving a head on the orifices of about 16 ft. The orifice device is a cluster of three adjustable orifices as described before, all operated simultaneously by a single small knurled wheel. Three $1\frac{1}{2}$-in. brass pipes convey the water to the tanks. The feed to any tank is cut off by a cock above the orifice. While these orifices are very accurate in the measurement of water, they are no longer used to accurately apportion the water to the lime in any fixed ratio. As the lime varies considerably in quality, any fixed proportion of water to lime would result in a corresponding variation in the temperature of the slaking lime; and as we deem it important to keep this temperature at 200 degrees for economy of slaking, the orifices are set to deliver the needed amount of water to attain this temperature. For a lime running 90 per cent. in CaO the ratio is about $3\frac{1}{2}$ to 1.

On account of the high temperature in the slaking tanks, there is a great deal of steam given off which it is imperative to keep from the automatic scales. For this purpose there was originally installed an exhaust system which took the steam from the tanks and discharged it outside the building. This was not entirely satisfactory as the exhaust piping continually choked up with hydrate of lime carried over by the draft and required constant attention. We have recently installed a device on one of the tanks which promises to rid us entirely of this trouble. Instead of adding the feed water in a solid stream as heretofore, it is sprayed into the tank at the bottom of the discharge chute from the scales. The water is forced through a narrow slot around the inside circumference of a hollow ring and forms a conical water curtain, effectually blocking any steam from entering the scale.

With the exception of caking in the bins, which is only of consequence when stored in such large quantities as we find necessary, the sulphate of iron is more easily handled than the lime. The iron used is a by-product of the tin plate and gal-

vanizing departments of the American Steel and Wire Company. It is readily dissolved and requires only streams of water across the bottom of the tank in which it is dissolved to prevent its settling. The tanks, two in number, are of $\frac{1}{4}$-in. steel 5 ft. by 5 ft. by 3 ft. deep and set with their tops 2 ft. above the floor, similar to the lime tanks. The covers are of $\frac{1}{8}$-in. steel in halves reinforced with angle iron. The spraying system at the bottom has been explained previously. The tanks are set close together and both discharge into a common funnel between them, whence the iron is carried in a 3-in. iron pipe to the uptake shaft, where it is added to the water.

Just above the tanks are the feeders for measuring the iron to be applied. They are novel in design and application. Essentially they consist of but two parts, a revolving wheel with axis horizontal and an orifice above, feeding a continuous stream of material on to the wheel. The wheel is 12 in. in diameter and has a flat face $5\frac{1}{2}$ in. wide. The orifice is in a vertical plate set 3 in. back of the vertical center of the wheel in order to prevent the material from flowing when the wheel is stopped. This orifice, whose bottom is the face of the wheel, is V-shaped and is made adjustable by means of a sliding gate in front of it operated by a micrometer screw. Wheel and orifice plate are held in a rigid box frame casting. The wheel is driven through a worm and wheel, the worms of both feeders being driven directly from the same shaft. Either or both feeders may be thrown in or out of action by means of a cone clutch at the worm. At either end of the shaft is a $\frac{3}{4}$-h.p., 500 volt variable speed interpole motor, each driving the shaft by a Morse chain through an automatic clutch, which latter acts in a similar manner to those described for the cross conveyer in the basement. The design of the clutch is entirely different from those mentioned, but will not be described here. The accuracy of these feeders in the measuring of iron depends entirely upon the constancy of speed of the wheel and consequently upon that of the motor. There are two factors tending to vary the speed, firstly, varying loads (as first constructed there was considerable friction between the wheel and case due to dust), and, secondly varying voltage (current is taken from trolley circuit, and voltage varies between 480 and 550). The first factor might have been overcome by a differentially wound motor, but the second was not so easily disposed of. No special winding would suffice, and there was no device on the market that we were aware of to serve our purpose. As the feeder itself was so simple, we were

loath to abandon it and so set to work on a speed regulator of our own design. We considered a variation of 1 per cent. either side as admissible, but in the apparatus now used there is a variation of only about one half of 1 per cent., and it has run for days with a variation of but one sixth of 1 per cent. The regulator is of the relay type and operates by varying the field strength of the motor, cutting out resistance in the field as the speed rises, and vice versa. It is isochronous in action, a spring ball governor keeping an arm poised between two electrical contact points as long as the speed is normal and making contact above or below as the speed rises or falls. The circuit so completed energizes one or the other of two small oscillating solenoids, which in turn throws a dog connected to its plunger into mesh with a ratchet wheel. The latter, keyed directly to the spindle of a rheostat, revolves it either right or left and cuts resistance in or out of the field as the case may be. With a given orifice setting, and a given sample of sulphate of iron run through the feeder a number of times, no variations in weight can be detected per 100 revolutions on a scale weighing to $\frac{1}{4}$ lb. But in order to test its accuracy under operating conditions and with varying degrees of dryness, samples from the cars were run through the feeder for a period covering about three months, as was also a single sample taken at the beginning of the test. Every test was made throughout the range of orifice opening, there being ten runs for each sample. Taking the average weight for each setting, there is in no case a variation of over one half of 1 per cent., and the average variations are within a quarter of 1 per cent.

The three slaking tanks and two heater tanks are driven by a line shaft hung in drop hangers from the pump-room ceiling. All boxes are roller bearing. The shaft is split near the center and the two sections connected by a clutch coupling. The shaft is driven by one or the other of two 10 h.p. motors, one at each end, through automatic clutches. In addition to the clutch coupling the shaft is divided into three sections and connected by two compression couplings. With this combination of divided shaft and duplicate motors, we are prepared to take care of almost any contingency which may arise. The drives from motor to shaft and from shaft to tanks are by high-speed silent chains enclosed in guards.

The heater tanks are operated by a clutch on the tank shaft. The slaking tanks are operated by magnetic clutches on the line shaft. These clutches are operated from a 500-volt

circuit and take something less than ½ ampere. They are wired so that the tanks may be started from either the pump-room or mixing-room floors. The switches are wired in series so that should a workman be working on the drive in the pump-room or in the tanks in the mixing-room, he has only to open the switch on his floor to prevent the clutch from being thrown in accidentally from the other floor.

With the exception of a small motor generator set for the scales, all motors are 500-volt, and of these latter all but one, a 4 h.p. vertical sump pump motor, are of the interpole type. The three crusher motors are wholly enclosed; all others are open. The current is taken from the water-works railway circuit, and the rapid fluctuations of voltage are particularly severe on motors, but these interpole machines have, so far, given only the best of service and have justified their additional cost. I might mention that in order to reduce the fluctuation of voltage as much as possible, a separate line was run from the generator house at Baden pumping station (four miles south) to the coagulant house, and the return was bettered by connecting the rail to the 7-ft. steel flow line between Baden and the Chain of Rocks. The connections are at each end of the pipe line and each is made of two 4-0 copper cables connected to the pipe by four 4-0 rail bonds riveted into the shell.

The two pump motors, the two line shaft motors and the seven conveying machinery motors are all controlled from a switchboard on the pump-room floor. The first four motors, being in the same room, are hand operated. The conveyer motors, being scattered throughout the building from basement to lantern, are operated by momentary contact push button control. Signal lamps on an independent 8-volt alternating current circuit indicate whether the distant motor is running or idle.

In operating the storage system (both lime and iron) where the crushers and elevators are run by independent motors, it is necessary, in order to prevent the possibility of accident, to start or stop the motors in proper sequence. In other words, in starting operations, the elevators should be started before the crushers, and in stopping the crushers should be stopped before the elevators. This has been accomplished by a device of our own design which electrically interlocks the push buttons above mentioned and prevents the starting or stopping of the motors in the wrong order. The device consists of a small solenoid mounted on the back of the board and whose plunger,

when down, prevents the push button in front from being closed. The solenoid is energized by the signal light circuit of its companion motor, which, when started or stopped (as the case may be), raises its plunger and permits its button to be closed. The circuit breakers of these motors are also interlocked by means of shunt trip coils, so that, should the elevator circuit be opened on account of overload of any kind, the crusher circuit will be simultaneously opened.

There are three separate feeders between Baden and the Chain of Rocks, two of which are used for the railway and one for the coagulant house. Should anything happen to the latter, either one or both of the former may be cut in, in its place. There is also at the Baden generator house two generators for supplying current, only one of which is run at a time. The accidental cessation of energy for any considerable length of time is, therefore, only a remote possibility, but to "make assurance doubly sure" there will shortly be installed in the machine shop at the Chain of Rocks an independent generating unit of sufficient size to run all motors with the exception of the storage system. The wires to the coagulant house will be run in an underground conduit.

It has been the aim throughout the design of this plant to install all moving parts in duplicate wherever possible and to provide such safety devices as would insure the maximum protection against breakdowns. Where the duplication of parts has not been possible, auxiliary appliances have been installed to perform the functions of such parts in case of accident.

A head foreman has entire charge of the plant. There are three watches of eight hours each, the operating force of each watch consisting of but three men — an assistant foreman and two helpers. Two men can run the plant, but it has not been thought advisable as yet to run with such a small force, especially at night. There is employed at present during the day a temporary extra watch to make such changes and additions as the operation of the plant has so far shown to be desirable.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 1, 1910, for publication in a subsequent number of the JOURNAL.]

ANNUAL ADDRESS.

By C. H. Bowman, President Montana Society of Engineers.

[Delivered before the Society at its 23d Annual Meeting, Butte, Mont., January 8, 1910.]

Gentlemen, — I submit herewith the 23d annual report of your President as required by our constitution and by-laws. Our society is in a flourishing condition; we have a membership of two hundred; four of these have been transferred to the corresponding list and one has been transferred to another society. This is the first report since the year 1899 which has had no deaths to record. Sickness has detained our past President, Mr. Kinney, at his home in Bozeman; we miss his presence and have expressed our sympathy and regret by our resolutions this morning.

This year is not notable for single great achievements but I can report, however, a splendid activity in general improvements, the lessening of costs in some of our largest works and a wholesome growth of all industries requiring engineering skill.

Among the smelters I can report that the new flue system and stack of the Boston and Montana Smelter at Great Falls, the largest engineering feat of this kind ever undertaken, were put into operation. The date of the final connection was June 12, 1909, and the system has been giving continuous satisfactory results since this date. The details of this work were described to you at our last annual meeting by Mr. Wheeler.

The East Helena Plant of the American Smelting and Refining Company has installed an experimental Dwight and Lloyd sintering machine for roasting and sintering ores. This machine has proven very successful and the company is now planning to install two more larger machines. It is entirely new, just reversing the operation of the Huntington and Heberlin pots. Instead of blowing air through the charge the ore is fed to moving grates which move over an air-tight wind box from which the air is drawn by means of a rotary fan. Just at the point where the grates begin to travel over the wind box, the charge is ignited by means of a gasoline jet. A mixture of the various ingredients of the charge must be thoroughly made and crushed to about $\frac{1}{8}$ in. and finer. A certain admixture of moisture

is also necessary. With careful attention the charge ignites readily and produces a most excellently sintered product, running between 3 per cent. and 4 per cent. of sulphur. The capacity of the present small machine is about 40 tons per day or about four times the capacity of the present reverberatory roasting furnaces.

The Washoe Smelter at Anaconda has passed a prosperous year of continuous operation, lessening expenses of operation to a notable extent and adding small improvements at various points. The bull jigs in the concentrator have been enlarged, resulting in cleaner concentrates and more coarse concentrates. The enlargement is 6 in. in width and 12 in. in length. In the converter department second class ore from Butte has been adopted for converter linings. By way of new development a dam of earth has been constructed forming an enormous settling pond for tailings and slimes escaping from the smelter. The primary object of the pond is to render the overflow water fit for irrigation purposes. The length of the dam is 6 150 ft.; it is 10 ft. wide at the top and averages over 12 ft. high.

The Butte Reduction Works has installed and now operates a concentrator expressly for the treatment of zinc ores. I am informed that the zinc ore now in sight in Butte mines may be mentioned in the millions of tons valued between $11 and $12 per ton at the mines. In view of this fact it would seem that the starting of this small concentrator treating some 200 tons per day may mark the beginning of a new impetus to the mining life of Butte. The concentration is effected through the use of two Pratt jigs, one Pratt sizer, 26 Overstrom tables and two Chilean mills, together with necessary crushers, rolls, trommels, screens, etc. The concentration is about 3 parts into 1; the concentrates average about 50 per cent. zinc, 2 per cent. copper, 30 oz. in silver and $1 in gold.

Another feature of interest at the Butte Reduction Works is the slime plant. The equipment consists of a series of large concrete settling tanks from which the thickened pulp is continuously drawn and treated on a series of slime tables. A series of some seven different tables is being tried out on these slimes; all things considered, the Craven table seems to be winning first honors. It is too early to comment upon the efficiency of the plant as a whole, but it may be mentioned that the product carries 12 per cent. to 14 per cent. copper, 14 to 20 oz. of silver per ton and 20 per cent. to 25 per cent. silica.

The data published by the various mining companies of the state indicated a very satisfactory situation. By way of develop-

ment in the Butte district over 27 miles of drifts, crosscuts, raises, shafts, etc., have been driven, distributed among the different mining companies quite in proportion to their holdings. This development work has disclosed ore bodies of copper which maintain the ore reserves fully equal to that of a year ago. The deepest shaft, the high ore shaft, is 2 800 ft. in depth and the appearance of the veins at this point offers no suggestion of the discontinuance of the copper ore veins with depth. Aside from the copper ore, millions of tons of zinc ore as mentioned above, have been opened up ready for mining.

Among the many changes and improvements which have lessened the expenses of operation and contributed to the efficiency and safety of the miner may be mentioned the more extensive adoption of electricity about the mines. New electric hoists have been installed at the Gray Rock and Modock mines and new electric pumps at the Leonard mine. Among the developments of the future may be the revision of our air compression plants; at present 6 500 h.p. is being used in these plants. The present operation is by steam, and will, no doubt, bid welcome to the cheaper electric power in course of time. The problem of operating a motor for hoisting has been solved at least to the extent of producing a machine that is making a good record in the beginning. So far as I can determine, small motors have been in use for some years but nothing has been installed until recently which has met the conditions imposed by our largest mines. The main conditions to be met are: The use of a 3-phase alternating current; the largest torque of the motor must be at starting, the moment when a load is started from the bottom of a shaft; the control for starting, stopping and reversing must be so substantial that injury cannot result from a momentary error or haste of the operator. The controlling device must also withstand almost continuous manipulation and be capable of moving the cable to within a few inches of a given mark. At the Gray Rock mine a 150 h.p. motor is used to hoist a load of 5 000 lb. with a speed 700 ft. per minute. At the Modock mine the hoisting drums are operated by a 225 h.p., 3-phase, 440 volt, 60 cycle, 12 pole, Westinghouse variable-speed induction motor. The motor runs at 600 rev. per min., giving the rope a speed of about 850 ft. per minute. The control is in part automatic, in order not to draw too heavily at one time on the generators supplying the current and in order not to throw too heavy a strain on the cable or other parts of the equipment. The automatic device supplies the current to the motor in proper quantities after the control

switch is thrown in. The time required to obtain full speed is predetermined and properly adjusted once for all time. Aside from this limiting condition there are nine forward speeds, a reverse and nine reverse speeds for the motor.

Previous to this year the Leonard mine had three electric pumps installed and now a fourth pump is being installed. The type is known as the Aldrich quintuplex pump, having a capacity of 600 gal. per minute, raising the water from a depth of 1 200 ft.

In other lines of metal, mining activities have been at a low ebb, chiefly on account of the low price of silver. The coal mines, however, have been prosperous. New mines have been opened up at Roundup by the Republic Coal Company, the Roundup Coal Company and at Red Lodge by the Northwestern Improvement Company. Each of these companies has practically developed and equipped a new mine this year. The work has been along the latest and most improved lines. The Cottonwood Coal Company at Stockett has opened up a new mine also. The mine is known as No. 6, and is connected with the existing tipple and plant by means of a cable tram 2 miles in length. No less than five other coal mines have added new tipples, screens, box car loaders and other improvements which have greatly added to the quality and output of Montana coal.

The increased use of electric power is made possible by a further development of our water-power plants, somewhat to the distraction of our more poetic friends. I cannot help being amused, quoting from one of our popular magazines, speaking of the magnificence of one of the falls: " But of late years it seems he has taken up with company rather beneath him. First of all, he has gone to work in a most plebeian, almost slave-like fashion, turning wheels and making lights and dragging silly little trolley cars about a straggling town. Also he hobnobs continually with a sprawling, brawling, bad-breathed smelter, as no respectable Titan should do." Credit be given to the engineer, the statement that he has gone to work is true, and I believe that our more sentimental friends will agree that this Titan, the waterfall, should be harnessed when they consider that the water power under present development at Great Falls effects a saving of 2 000 000 tons of coal per year, which at $5 per ton amounts to about $10 000 000 per year in round numbers, to say nothing of future possibilities. This certainly would be an extravagant price to pay for a fanciful exhibition.

Viewing the more concrete facts, the plant at Rainbow Falls

is designed for an average flow of 3 500 second-ft. The development consists of a timber crib, rock-filled dam, 26 ft. high, 67 ft. wide on the base, with an apron 49 ft. wide on the downstream side. The dam is 1 145 ft. between abutments, all of which is completed with the exception of 57 ft., which is being closed. The waste water is controlled by five gates 8 ft. by 10 ft. in dimensions, set in heavy concrete at the south end. The water supply to the penstocks is controlled at the north end by eight gates, each 8 ft. in diameter. These gates deliver the water to two steel pipes 15½ ft. in diameter and thence to a regulating reservoir located 2 400 ft. from the dam and above the power house. These steel pipes are about half completed; they are being laid side by side, under about 2 ft. of earth. The regulating reservoir is about two thirds completed and is being constructed of concrete; it covers about 2 acres of area. The magnitude of thc work can be gathered by noting the amount of material involved in the structure.

The Dam.	
Timber in dam	4 560 000 B. M. ft.
Concrete in dam and abutments	10 474 cu. yd.
Loose rock filling in dam	25 003 cu. yd.
Steel work about dam	675 tons
Penstocks.	
Excavation, earth and rock	49 150 cu. yd.
Steel pipe in place	1 875 tons
Reservoir.	
Excavation, earth and rock	40 454 cu. yd.
Concrete in place	8 250 cu. yd.
Steel in place	180 tons
Power House and Tailrace.	
Solid rock excavation	41 150 cu. yd.

The steel and brick power house together with the generators, water wheels and accessories, are not in place to date; they will form excellent material for a subsequent discussion.

The work completed during the year at the Big Falls of the Missouri consists of grading 2 miles of wagon road and building a permanent shear or coffer dam, the total cost being about $59 000.

At the Black Eagle Falls, the head gates have been raised with concrete construction.

The Missouri River Power Company is also conducting extensive operations at Hauser Lake and at Holter, which will

soon place it in a position to furnish 42 700 h.p. to power consumers. Details for publication are not to be obtained at the present writing.

Power lines for the transmission of electricity are being threaded rapidly to points of industry, supplying current to our increasing industrial plants. A double pole line has been constructed from Livingston to Big Timber, a distance of 33 miles, leaving power also at Springdale for Hunters Hot Springs. A transmission line is also constructed from the Madison Plant to Trident, 36 miles, supplying power to the Three Forks Portland Cement Company. It is interesting to note that the power required by this company is 1 800 kw. and the output of the plant is about 1 800 barrels of cement per day. A steel transmission line has been built from the Madison Plant to Butte; its length is 61 miles. The line has a capacity to carry 7 500 kw. at 46 200 volts. The towers are 45 ft. high, spaced on the average 660 ft. apart, the longest span being 2 500 ft. Two steel tower lines are under way from Great Falls to Butte; the general construction is the same as the Madison-Butte line, except that the line is insulated for 100 000 volts instead of 46 200 volts.

Linked with these larger developments are the small improvements, almost too numerous to mention in a brief review. There is one, however, which deserves mention on account of its precedence; we have realized our first interurban railroad. The road at present extends from Bozeman to Saleville, a distance of 17 miles. There are eleven side tracks along the route for the convenience of the farmers in transporting their crops to market. The power is obtained from the Madison River Power Company and the equipment consists of one large passenger car and one heavy freight motor car capable of handling the supply of box cars. The Gallatin valley offers many resources to stimulate further extensions of this line.

The railroads operating in Montana have been active during the past year in adding improvements, building new stations, lessening grades at various points and improving road beds generally. The Chicago, Milwaukee & Puget Sound Railway has been most active since its line was nearly completed through Montana during the year. The construction of the road bed in western Montana was finally completed in March, the last work being the tunnel at Garrison and the large cut at Hellgate Station. The bore of the tunnel at Garrison was completed in June, 1908, but almost on the day of its completion there occurred a slide and caving which resulted in the loss of some 300 ft. of work. The

problem of retunneling was difficult on account of the loose material and broken timber. The method employed was to drive a small drift at the foot of each bench wall. These drifts were then filled with reënforced concrete, after which another drift would be driven on top of the concrete already in place; this drift would likewise be filled with concrete and the operation repeated until a complete section of the tunnel was constructed. The Hellgate cut above mentioned is a three-track cut constructed jointly by the Chicago, Milwaukee & Puget Sound Railway and the Northern Pacific Railway. It compares favorably with the largest cuts in the world. Its length is 2 000 ft., maximum depth 137 ft. and the yardage contained was 623 000, 90 per cent. of which was solid rock. The laying of track on the entire extension was finally completed in April, 1909, the last spike being driven near Gold Creek almost at the same spot where the last spike of the Northern Pacific had been driven in 1883.

Including the work on the St. Paul Pass, over 13 000 ft. of tunnel is being lined with concrete. The replacing of various timber structures with steel and the filling in under others have been commenced. In filling under bridges the engineers have adopted sluicing wherever water is available. In this line nothing more has been done than to construct flumes and get things in readiness for operation in the spring. This work will be watched with interest since no solid banks of material are available, but on the contrary, sluicing will have to extend over a large area with only a few feet in depth susceptible to such operations.

A new railroad is being constructed in the southwestern portion of Montana, the Gilmore & Pittsburg Railway, connecting Armstead, Mont., with Salmon City, Ida. The track laying has proceeded nearly to Bannock Pass, 47 miles from Armstead, using 70-lb. rails on the straight line and 80-lb. rails on the curves and grades. The total length of the line including switches is 135 miles. The main divide is crossed about 47 miles from Armstead where a tunnel of 700 ft. has been constructed. The maximum grade on the Montana side is said to be 2.49 per cent. and on the Idaho side 2.36 per cent. The work is being conducted with the best improved machinery, including track-laying machine, steam shovels, etc. The present equipment consists of 5 locomotives and about 150 freight cars.

Among the larger extensions of the railroads may be mentioned the Billings and Great Northern. Most of the work was completed during the previous year and described at our last

meeting. During last summer the road was equipped and through service established from Kansas City to Seattle by way of Billings and Great Falls.

Your last report, made by President Wheeler, contained a very complete account of the irrigation projects and reviewed the progress of the work up to the close of 1908. Mr. Savage, of the Reclamation Service, informs me that during the past year approximately $3 000 000 have been expended in furthering these projects, the main ones being known as the Sun River, St. Mary, Milk River, Lower Yellowstone and Huntley projects. The first units will place about 125 000 acres under cultivation; of this acreage about 90 000 acres are now being cultivated. The Dodson Dam for the Milk River project is now nearly completed as well as the canal system and allied structures. The dam has a height of 28 ft. above the stream-bed and its length over all is 360 ft. The top 5 ft. of the dam operates automatically to discharge flood waters, thus keeping the reservoir below a fixed level. The Lower Yellowstone dam which has been under construction for some years will be completed in about two months. This structure has a height of 20 ft. and a length of 700 ft. Its purpose is to divert water into the main canal of the Lower Yellowstone project. The structure will be called upon to pass a discharge over its top of over 100 000 sec.-ft. The other projects are advancing continuously, as well as three lesser works on three Indian reservations, i. e., Fort Feck, Blackfoot and Flathead reservations.

Our city of Butte has witnessed an enlargement of our water system. The Butte Water Company has completed its Moulton dam, imponding normally 260 000 000 gal. of water. A 12-in. conduit carries the water to small distribution reservoirs north of Walkerville, from which it may be distributed to all parts of the Butte system by gravity. The length of the dam is 509 ft. and the height is 60 ft.; it is of earth construction with a concrete core wall. There are 85 000 cu. yd. of earth embankment, 5 200 cu. yd. of concrete and 5 658 sq. yd. of brick paving entering into the construction. The spillway is 10 ft. deep by 20 ft. wide. The maximum depth of the core wall which was carried from the solid foundation is 40 ft., and the minimum is 16 ft. The core wall tapers from 7 ft. at the base to 2 ft. at the top. It required the excavation of 2 700 cu. yd. of earth.

I know there has been much more good engineering work accomplished in the state this year than I have reported. Some of it will appear in special papers to-day; other work will be

reported at future meetings, when a more accurate and complete record can be given than would be possible at this time.

I wish to express my thanks to the officials and their staffs of the various companies and organizations mentioned in this report; they have all been most courteous in supplying all that I have recorded.

On the whole, the year has been a prosperous one; a comparatively small band of engineers has directed the expenditure of millions of dollars and produced commodities and works which have returned many times this expenditure in comforts and wealth to our people. Upon this you are to be congratulated, and for which you are entitled to the satisfaction that only the giver, the doer of good works, can have. Though modest men you be, you are entitled to hold your heads high, for you are not men of the hour or day, but men who build and provide for the ages. So you are gathered together by this bond of comradeship, this bond of unselfish effort. May these few days of relaxation, reflection and friendly exchange of ideas, be an inspiration to you as well as supply food for contentment.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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THE DETERMINATION OF ORDINARY HIGH WATER PLANE ON THE PACIFIC COAST OF THE UNITED STATES.

A DISCUSSION BY D. E. HUGHES AND OTTO VON GELDERN.

[Read before the Technical Society of the Pacific Coast, February 4, 1910.]

INTRODUCTION.

BY OTTO VON GELDERN.

WHAT is ordinary high tide? This question, at first thought, may be of no particular interest to any one.

To the navigator the plane of high water is of importance because it shows him that in shallow channels he may count upon an additional 5 or 6 or 7 ft. of depth, whatever the case may be, over and above the datum plane of his chart, which is usually the lowest tide. The low water and the high water become commercially important in that ocean traffic and marine insurance must give them serious consideration. In wharf building, and in the water-front work of large cities, the highest tidal plane becomes a gage for the elevation of wharves. All warehouse structures utilized in shipping are built with due consideration for the extreme range of the tide, while the low-water level, again, gives us concern in establishing the height of important water-front foundations and so on. Sewer outlets, too, require thoughtful consideration of the higher and lower planes. We see what an important part the range of the tide plays in our daily life. On the bordering tide lands certain

industries, such as fishing, oyster cultivation, clam digging and others, look to the low-water boundary with a business interest.

Thus, while the range and its limits have a direct bearing upon the affairs of man, *ordinary* high water, an ambiguous and arbitrary term, has not given any anxiety to any one. Nor would the problem of what constitutes this plane have arisen if the three words had not been made a legal term in fixing the landward boundary of tide land.

That this question has become of great importance to the commonwealth is borne out by a recent opinion rendered to the city council of San Diego on January 27, 1910, by city attorney W. R. Andrews, who, after an exhaustive study of all the conditions, past and present, holds that

> "The city of San Diego has no right, by reason of her proprietorship in the pueblo lands, to any land below the line of ordinary high tide, nor to any of the soil beneath the waters of the bay of San Diego."

In referring to this opinion it is very interesting to examine the argument for a few moments. The question submitted was: Is the city the owner of lands below ordinary high tide, and, if so, what method should be adopted to recover them?

The old towns of California became the owners of what are known as Pueblo lands under conditions somewhat different from ordinary methods, so that mooted questions of this character are not of infrequent occurrence. The picturesque history of our state under three different governments is responsible for many of the ambiguities that have arisen since originally valueless possessions became of great importance.

Upper and Lower California belonged to Mexico from the time of her independence, having been a part of the dominion of Spain. The Spanish crown, in order to induce colonization of these distant and almost fabulous territories, placed four square leagues of land at the disposal of every pueblo or town for the benefit of its local population, to whom it was parceled out in smaller areas. Mr. Andrews states that it seems to have been the right or privilege of the chief official of the pueblo, the alcalde, or of the town council, as the case may have been, to dispose of small quantities of this land in order to defray the expenses of the local administration.

The harbor of San Diego was originally explored by Sebastian Vizcaino in 1603, but there was no settlement there under Spanish control until 1769, when the presidial mission was established,

San Diego, California, in 1846.

which in 1835 was converted by Mexican law into the pueblo of San Diego.

The American flag was raised at the old town in July, 1846, but the turbulent times and the animosity of the Mexican settlers did not permit an establishment of American authority until later on. The battles of December 6 and 7, 1846, at San Pasqual, and January 8 and 9, 1847, known as the battle of Los Angeles, fought between the Americans and the Mexicans, broke Mexican rule forever in California, and the Californian yielded without further struggle to the authority of the United States. This interesting history was related in detail by Major W. H. Emory, of the topographical engineers, in his "Notes of a Military Reconnoissance," published as a public document in 1848, in which the old town of San Diego, where the flag was raised, is described as situated at the foot of a high hill, on a sand flat two miles wide, reaching from the head of San Diego Bay to False Bay. The illustration showing the location of the early settlement is from the same document.

In 1845, while the pueblo was as yet a part of the Mexican territory, Mr. Andrews relates that "in order to have the right to the pueblo lands confirmed, a survey was made, showing the exterior boundaries of the pueblo of San Diego. This survey was made by Capt. Henry D. Fitch under the authority of the alcalde of San Diego, and the map so made was subsequently approved by Pio Pico, the then governor of California."

The city attorney takes up the question whether or not the pueblo of San Diego was entitled legally to any part of the land lying between the line of ordinary high tide and low water, — or the land under the bay, — and makes a very thorough analysis of the conditions. He states,

"An idea has prevailed among a great many people that a pueblo bounded by a water front acquired a title under the Spanish or Mexican law to lands which were below the line of ordinary high tide,"

but he finds no authority for any such assumption. Continuing his inquiry, he quotes the Roman law, on which the Spanish law is founded, as well as that of Mexico, and he states that the Roman law is substantially the same as the common law on this point.

"The Mexican law," continues the city attorney, "has this to say on the subject of shores:

"'The things which belong in common to all the living creatures of the world are the air, rain, water, the sea and its

shores, for every living creature may use them according to his wants. And, therefore, every man may enjoy the use of the sea and its shores, either for the purpose of fishing or navigation, or doing there whatever else he may conceive advantageous to him.

" 'Every man who chooses may build a house or cabin upon the seashore as a retreat, and he may erect there any other edifice whatever to serve his purpose; provided, he does not thereby interfere with the use of the shore which every one has a right in common to enjoy. He may also build galleys there or any other vessel whatever; or stretch and mend his nets, and when he is there or employed in these, or other purposes of a similar nature, no one has a right to disturb him. And by the seashore is understood all that space of ground covered by the waters of the sea in their highest annual swells, whether in winter or in summer.' "

The city attorney states that it will be noticed that

" It is not the line of ordinary high tide which by Mexican law would be the boundary, but the line of extraordinary high tide, so that the rule against the city under the Mexican law was harsher than that followed by the American courts."

He thinks that, outside of any decision by the courts of our own state or of the United States, the pueblo of San Diego as a Mexican town never had any right, legal or equitable, to any land below the line of extreme high tide.

All the preceding is extremely interesting, but it is rather a matter of law with which the engineer is not concerned; the subject begins to be of direct interest to him professionally, however, if the law should find it necessary to define the term "ordinary high water." There is no doubt that this important subject will come up again and again in many of our Pacific coast harbors until some status has been obtained to clear away the confused ideas which are prevalent. Justice Field has rendered a decision defining the term "ordinary high water," to which reference will be made later on. You will agree with me, after you read it, that his definition left the matter in a greater confusion than ever, for any man attempting to make an interpretation on the ambiguity of Justice Field's explanation will find himself face to face with an absolute and unintelligible absurdity.

It will pay to establish tidal data in every harbor; that is, to gather detailed information to fix definitely the elevation of planes that are so glibly used without knowing exactly what they imply.

It was found advantageous and perhaps necessary, for instance, to send an expert, Mr. W. Bell Dawson, M. Inst. C. E.,

to the Pacific coast of Canada to decide upon planes of reference for the height of the tide in the various harbors of British Columbia. Considerable confusion existed there, and there appeared to be no definition for the principal harbor planes, which became a greater and greater necessity as the importance of the harbors grew. Mr. Dawson came in 1905 and began his studies for the definition of tidal planes for harbor purposes, and continued them for several years.

While the same subject was under discussion at San Diego, Judge Haines, one of the legal representatives in this important controversy, consulted his friend, Mr. D. E. Hughes, a civil engineer residing in Los Angeles, on the theory underlying the tides and tidal effect, of which Mr. Hughes had made a thorough study in relation to certain harbor work on the Pacific coast, with which he had been connected for years. The following deduction of the ordinary high-water plane for San Diego harbor was written by Mr. Hughes to Judge Haines in a letter dated November 22, 1908, in which he not only imparts the information which had been requested of him, but also presents a thorough and conscientious argument of his premises and final results. The engineer will find Mr. Hughes' deductions of great interest. It is worthy of his time and thought.

He pleads for the average of the higher high waters, which at San Diego is 5.5 ft. above the plane of mean lower low water. After reading Mr. Hughes' opinion I considered his plane too high and suggested the mean of all the high waters, 4.8 ft. above datum, for defining ordinary high water.

Preface.

BY D. E. HUGHES.

A brief history of land ownership will give definitions of certain terms and the necessity for a discussion on the statutory phrase, "ordinary high-water mark."

In the beginning, all land and all water belonged by divine right to the king, whose will was law and who willed to dispose of lands to his subjects for husbandry, but held the waters, with the lands under them, as free as air and sunshine for the use of all. Thus, lands above the water became proprietary in character or susceptible of private ownership, while lands under water continued to be held by governments in trust for the benefit of the public, and under the old Roman law the *extreme* high-water mark was the dividing line between them. During

the centuries, through individual selfishness and public indifference, the dividing line came down to *ordinary* high-water mark.

When the United States acquired independence, each state became sovereign and succeeded to the rights of the king and owned, with its boundaries, all lands under water and all lands above water that had not passed into private ownership. A few years later, at the request of Congress, the several states ceded to the United States their unappropriated territory to be disposed of for the purpose of paying the Revolutionary debt.

The United States on acquiring additional territory held for the time the lands therein below water in trust for the states to be created, who in turn were to hold them in trust for the public forever.

The United States, in the administration of public lands, found large areas of swamp and overflowed lands which, though above the level of ordinary high-water mark, were inundated so frequently as to render them unfit for cultivation without reclamation and, since the individual settler was not able to reclaim and the government was not then ready to help, such swamp and overflowed lands were in 1851 ceded to the states that they might be reclaimed by state power and authority.

Thus California, as well as some other states, became possessors of *two* distinct classes of lands, holding the class *below* ordinary high-water mark in trust for the public, — the people of the day and the people to come after them, — and holding the other class, swamp and overflowed lands *above* ordinary high-water mark, as proprietor, such lands to be reclaimed and sold or sold and reclaimed.

The land held in trust is of two sub-classes, namely, *submerged land*, which is *below* ordinary low-water mark, and *tide land*, which is *above* ordinary low-water mark but below ordinary high-water mark, and constitutes the *shores* of our waters.

The proprietary land includes swamp land in the mountains, overflowed lands along rivers outside the channels, and *salt marsh* around bays and inlets, bare at ordinary high tide, but covered by the higher waters.

The segregation line at the upper limit of salt-marsh land reached by only the highest tides is not the subject of our discussion, but the partition line between tide-land and salt-marsh, — between trust land and proprietary land, — which line is *ordinary high-water mark*, a term not yet defined by our own courts with sufficient precision.

This line is important not only in limiting private rights

and conserving water frontage for public use, but in that it bounds the water area over which the constitutional power of the federal government, to do all things for the regulation of commerce, is paramount.

Deduction.

BY D. E. HUGHES.

To get a proper conception of the averages of tides, whether from direct observations or from the tide tables which have been calculated from such observations, many things are to be considered.

First: Not the calendar months, but the lunar months, are to be used; that is, we must note the age of the moon at beginning and continue to a like age of a succeeding moon, say, from new moon to some later new moon, or from a full moon to another full moon.

Second: Since lunar tide depends on the distance of the moon from the earth, we should include a period just covering one or more such cycles of distance, say, from perigee (*P*) to perigee, or from apogee (*A*) to apogee.

Third: Since tides also depend upon the declination of the moon, our period of time should begin and end with the moon in the same declination, whether at the most northerly limit (*N*), or the most southerly limit (*S*). The next best averages would be obtained by using halves of cycles, say, from new moon (●) to some full moon (○), or from a perigee (*P*) to some apogee (*A*), or from a most southerly declination (*S*) to a most northerly one (*N*), or *vice versa*.

Consulting the San Diego tide tables for 1908, United States Coast and Geodetic Survey, suppose we start at new moon (●) on January 3. We should get our first approximation to the truth by continuing to new moon (●) on February 2, and a good approximation it is, too, for note that the moon was farthest south (*S*) and near perigee (*P*) at time of starting January 3, and nearly so again on February 2. If we continue our observations or calculations to next new moon (●), on March 2, we are again near perigee (*P*), which is good, but not near south (*S*), but near equator (*E*) instead, which is not so good, and may make the two months' work be farther from the truth than the one month's observations.

Continuing another lunar month to new moon (●), March 31, only puts us farther from south (*S*) and also from perigee (*P*).

The next acceptable stopping place after February 2 is at

Predicted Tides at La Playa, San Diego Bay, California, from new moon Jan. 3, 1908 to new moon Feb. 2, 1908, from Tide Tables for 1908, by U.S.C.& G.S.

Scale;- Squares represent vertically 1 foot, horizontally, 1 lunar day, averaging about 24 hours and 51 minutes.

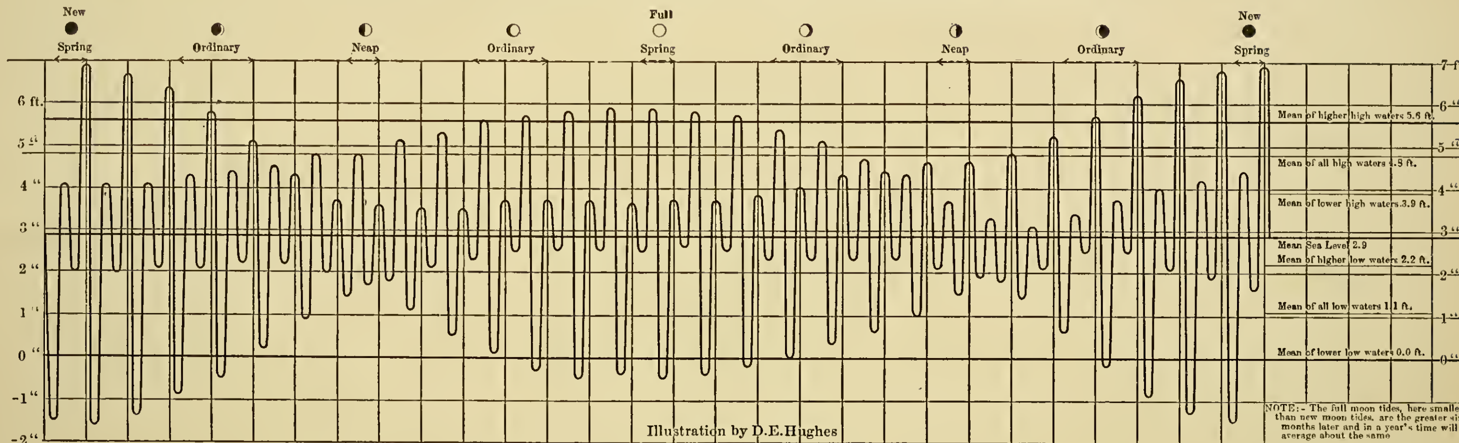


Illustration by D.E.Hughes

showing graphically,
(in support of his contention)
that the alternate lesser oscillations
are so small in comparison with the others
as to make unreasonable their inclusion
in determining for practical purpose either
"Low Water Mark" or "High Water Mark."

full moon (☺) on June 14 or July 13, for then we are again near both (*S*) and (*P*) and we have a full number and a half of these lunar periods. A good short period would be from June 14 to July 13, or from July 13 to August 11, for each about includes all the variations of the moon as to age, declination and distance.

The best long period of the year 1908, beginning on January 3, ends on December 23, when the moon is again new and also farthest south and near perigee; also the time being nearly a year, the sun, too, which has its influence on tides, has about completed its own annual period of distances and of declinations, for it is nearest the earth in January and farthest from it in July, and in declination it is farthest north on June 21 and farthest south December 21.

To get the best theoretical results, considering the variations in distances and declinations of both sun and moon, both independently and with respect to each other, our period must be extended to about 18.6 years, for in that time the sun and moon return to very nearly the same relative positions with respect to the earth.

But we are now going beyond the practical in our thoughts to determine the mean height of the sea with respect to the shore at any given place down to some small fraction of an inch, when some trifling unobserved upheaval or subsidence of the earth's surface may nullify the refinement, or some slight change in local average barometric pressure, due to change in ocean currents, or to the Salton Sea, or to prevailing winds, or what not, may defeat our purpose. Let the barometer at a given place average a hundredth of an inch lower and the sea will average an eighth of an inch higher. Thirty inches of mercury balance 33 ft. of sea water.

Now let us average the predicted tides for the lunar month from January 3, 1.43 P.M., to February 2, 0.36 A.M., which are the exact times for the phase of new moon in 1908 for the Pacific coast.

The tides are shown graphically on a drawing reproduced on page 222.

Observe that in adding we jump across from one column to another, selecting the lower lows and the higher highs. The undulation which gives the higher high at new moon wanes and becomes the lower high at full moon and *vice versa*, and so with the low waters. But the sequence remains the same; that is, the higher high is followed by the lower low. If in our additions we remain in the same columns throughout the year,

we should find the two mean low waters nearly alike, also the two mean high waters, the difference being the slight excess of the average tide on the side of the earth towards the moon, called direct tide, over the other or opposite tide.

	Low.	High.	Low.	High.	
●	—1 6	4.1	2.0	6.9	Spring.
	—1.6	4.1	2.0	6.7	
	—1.4	4.1	2.1	6.4	
	—1.0	4.3	2.1	5.8	" Ordinary."
	—0.5	4.4	2.2	5.1	
	0.2	4.5	2.2	4.3	
	0.9	4.8	2.0	3.7	
☽	1.4	4.8	1.7	3.6	Neap.
	1.8	5.1	1.1	3.5	
	2.1	5.3	0.5	3.5	
	2.3	5.6	0.1	3.7	
	2.5	5.7	—0.3	3.7	" Ordinary."
	2.5	5.8	—0.5	3.7	
	2.5	5.9	—0.4	3.6	
○	2.5	5.9	—0.5	3.7	Spring.
	2.6	5.8	—0.4	3.7	
	2.5	5.7	—0.2	3.8	
	2.3	5.4	0.0	4.0	
	2.3	5.1	0.3	4.3	" Ordinary."
	2.3	4.7	0.6	4.4	
	2.3	4.3	1.0	4.6	
☾	2.1	3.7	1.5	4.6	Neap.
	1.9	3.3	1.8	4.8	
	1.4	3.1	2.1	5.2	
	0.6	3.4	2.5	5.7	
	—0.2	3.7	2.5	6.2	" Ordinary."
	—0.9	4.0	2.1	6.7	
	—1.3	4.2	1.9	6.8	
●	—1.5	4.4	1.6	6.9	Spring.
29)	—0.9	112.3	63.5	162.4	
	0.0	3.9	2.2	5.6	
	L.L.W.	L.H.W.	H.L.W.	H.H.W.	

SPRINGS.

	—1.6	4.1	2.0	6.9	
	—0.5	3.7	2.5	5.9	
	—1.5	4.4	1.6	6.9	
	—0.4	4.2	2.1	5.7	(Feb. 17)
4)	—4.0	16.4	8.2	25.4	
	—1.0	4.1	2.1	6.4	

NEAPS.

	1.4	3.6	1.7	4.8
	1.5	3.7	2.1	4.6
2)	2.9	7.3	3.8	9.4
	1.5	3.7	1.9	4.7

" ORDINARY."

	—1.0	4.3	2.1	5.8
	—0.5	4.4	2.2	5.1
	0.1	3.7	2.3	5.6
	—0.3	3.7	2.5	5.7
	0.0	4.0	2.3	5.4
	0.3	4.3	2.3	5.1
	0.6	3.4	2.5	5.7
	—0.2	3.7	2.5	6.2
8)	—0.5	31.5	18.7	44.6
	0.0	3.9	2.3	5.6

AVERAGE OF SPRINGS AND NEAPS.

	—1.0	4.1	2.1	6.4
	1.5	3.7	1.9	4.7
2)	0.5	7.8	4.0	11.1
	0.2	3.9	2.0	5.5

$$\frac{0.0+3.9+2.2+5.6}{4}=2.9=\text{mean sea level}$$

Average of tides from full moon July 13, 1908, 1.48 P.M., to full moon August 11, 1908, 8.59 P.M., Pacific time:

	Low.	High.	Low.	High.	
☉	2.2	6.8	—1.5	4.0	Spring.
	2.0	6.7	—1.4	4.2	
	2.0	6.4	—1.1	4.3	
	2.0	6.0	—0.6	4.5	
	1.9	5.3	0.0	4.6	" Ordinary."
	1.9	4.6	0.7	4.8	
	1.8	4.0	1.3	4.9	
☾	1.6	3.7	1.8	5.0	Neap.
	1.1	3.5	2.2	5.3	
	0.6	3.5	2.4	5.5	
	0.1	3.6	2.5	5.7	
	—0.3	3.8	2.5	5.8	" Ordinary."
	—0.5	3.6	2.5	5.8	
	—0.5	3.5	2.5	5.8	
●	—0.5	3.7	2.6	5.7	Spring.
	—0.4	3.9	2.5	5.5	
	—0.2	3.9	2.3	5.3	
	0.1	4.0	2.2	5.0	
	0.4	4.3	2.2	4.6	" Ordinary."
	0.7	4.5	2.2	4.2	
	1.1	4.6	2.0	3.7	
☽	1.5	4.6	1.9	3.3	Neap.
	1.9	4.8	1.5	3.1	
	2.1	5.1	0.8	3.2	
	2.5	5.5	0.1	3.5	
	2.5	5.9	—0.6	3.9	" Ordinary."
	2.3	6.2	—1.0	4.1	
	2.0	6.6	—1.3	4.4	
☉	1.7	6.7	—1.3	4.6	Spring.
	29)0.4	113.2	63.1	162.4	
	0.0	3.9	2.2	5.6	

SPRINGS.

	—1.5	4.0	2.2	6.8	
	—0.5	3.7	2.6	5.7	
	—1.3	4.6	1.7	6.7	
	—0.7	3.6	2.6	6.0	(June 28)
4)	—4.0	15.9	9.1	25.2	
	—1.0	4.0	2.3	6.3	

NEAPS.

1.6	3.7	1.8	5.0
1.5	3.3	1.9	4.6
2)3.1	7.0	3.7	9.6
1.6	3.5	1.9	4.8

" ORDINARY."

	—0.6	4.5	2.0	6.0
	0.0	4.6	1.9	5.3
	0.1	3.6	2.5	5.7
	—0.3	3.8	2.5	5.8
	0.1	4.0	2.2	5.0
	0.4	4.3	2.2	4.6
	0.1	3.5	2.5	5.5
	—0.6	3.9	2.5	5.9
8)	—0.8	32.2	18.3	43.8
	—0.1	4.0	2.3	5.5

AVERAGE OF SPRINGS AND NEAPS.

—1.0	4.0	2.3	6.3
1.6	3.5	1.9	4.8
2)0.6	7.5	4.2	11.1
0.3	3.8	2.1	5.6

The above results are practically the same as before, though the earth is in aphelion in July and in perihelion in January.

Let us average the spring tides at La Playa for the year 1908:

New Moon.

—1.6	4.1	2.0	6.9
—1.5	4.6	1.6	6.9
—1.1	5.0	1.1	6.6
—0.4	5.5	0.5	6.0
—0.4	4.5	1.5	6.1
—0.7	3.7	2.4	6.2
—0.7	3.6	2.6	6.1
—0.5	3.5	2.5	5.8
—0.3	4.2	2.2	5.5
0.2	4.8	1.7	5.1
—0.2	3.9	1.6	5.9
—0.8	3.8	1.6	6.3
—1.3	3.8	2.2	6.6
13)—9.3	55.0	23.5	80.0
—0.7	4.2	1.8	6.15

(Average of new moon tides.)

Full Moon.

—0.5	3.7	2.5	5.9
—0.4	4.2	2.1	5.7
0.1	4.8	1.5	5.3
0.1	4.9	1.1	5.6
—0.6	4.2	1.6	6.2
—1.3	3.8	2.2	6.6
—1.5	4.0	2.0	6.8
—1.3	4.4	1.7	6.7
—0.9	5.0	1.0	6.5
—0.3	5.7	0.3	5.9
—0.8	4.1	1.5	6.3
—1.0	3.9	2.1	6.4
12)—8.4	52.7	19.6	73.9
—0.7	4.4	1.6	6.15

(Average of full moon tides.)

—9.3	55.0	23.5	80.0	
—8.4	52.7	19.6	73.9	
25)—17.7	107.7	43.1	153.9	
—0.7	4.3	1.7	6.2	(Average of all springs.)
L.L.W.	L.H.W.	H.L.W.	H.H.W.	

$$\frac{-0.7 + 4.3 + 1.7 + 6.2}{4} = 2.9 \text{ ft.} = \text{mean sea level.}$$

While the new moon tides average about the same as the full moon tides in a year's time, there is generally a considerable difference, as seen above, in any one month. If we select the greatest, namely, the first four and last one of the above new moon tides and the last eight of the full moon tides, we have as the average of the thirteen greatest tides of the year, which has no special name:

—1.0	4.5	1.5	6.5
L.L.W.	L.H.W.	H.L.W.	H.H W.

Average of *neap* tides at La Playa for the *year* 1908:

☽ Moon on 1st Quarter.

1.4	3.7	2.0	4.8
1.7	3.5	2.0	4.6
1.3	2.9	2.8	4.4
1.0	3.2	3.1	4.2
0.9	3.7	3.4	3.8
0.7	3.7	3.4	4.0
1.6	3.4	2.4	4.5
1.5	3.1	1.9	4.8
1.3	3.1	2.3	4.8
0.8	3.0	2.8	4.8
0.3	3.8	2.7	4.5
0.2	4.0	2.9	4.4
0.8	4.4	2.4	4.4
13)13.5	45.5	34.1	58.1
1.0	3.5	2.6	4.5

☾ Moon on 3d Quarter.

1.8	3.3	1.9	4.6
1.3	3.1	2.2	4.8
0.6	3.4	3.2	4.9
0.3	3.4	2.9	4.8
0.1	4.3	2.8	4.5
0.3	4.3	2.3	4.5
1.3	4.0	1.6	4.9
1.3	3.3	2.4	4.8
1.0	3.1	2.9	4.6
0.7	3.3	2.7	4.3
0.8	3.7	2.2	3.8
1.3	3.6	3.2	4.1
12)10.8	42.8	30.3	54.6
0.9	3.6	2.5	4.5

13.5	45.5	34.1	58.1	
10.8	42.8	30.3	54.6	
25)24.3	88.3	64.4	112.7	
1.0	3.5	2.6	4.5	(Average of all neaps.)
L.L.W.	L.H.W.	H.L.W.	H.H.W.	

$$\frac{1.0 + 3.5 + 2.6 + 4.5}{4} = 2.9 \text{ ft.} = \text{mean sea level.}$$

Average of all *springs* and *neaps:*

	—17.7	107.7	43.1	153.9
	24.3	88.3	64.4	112.7
50)	6.6	196.0	107.5	266.6
	0.13	+3.92	+2.15	+5.33

$$= \frac{11.53}{4} = 2.9 = \text{mean sea level.}$$

Final Summary.

	L.L.W.	L.H.W.	H.L.W.	H H.W.
Average of all tides at La Playa for a number of years, as given by the United States Coast and Geodetic Survey...........................	0.0	4.1	2.0	5.5
Average predicted tides for the lunar month from January 3, 1908, to February 2, 1908.....................	0.0	3.9	2.2	5.6
Same from July 13 to August 11, 1908..	0.0	3.9	2.2	5.6
Average of all predicted spring tides in 1908...........................	—0.7	4.3	1.7	6.2

	L.L.W.	L.H.W.	H.L.W.	H.H.W.
Average of the thirteen greatest monthly tides	—1.0	4.5	1.5	6.5
Average of all predicted neap tides in 1908	1.0	3.5	2.6	4.5
Average of all "ordinary" tides recurring between springs and neaps, which is practically the same as the average of all tides, or	0.0	4.1	2.0	5.5

I arbitrarily took *two* of the intermediate tides between spring and neap as representing the "ordinary." Had four been taken instead, the average would have been practically the same.

I will say that during my five years' residence at Fort Rosecrans, near La Playa, I had frequent occasions, especially during surveys and time of dredging, to observe the tides and that I found them to agree remarkably well with the predicted heights given in the published tide tables. I, therefore, believe that the averages determined from the tide table and given in this paper are very nearly correct for the vicinity of La Playa. But at the east end of the bay there may be a considerable difference. At the far end of a bay the tide can hardly fall as low as it does near the outlet, but in many cases, depending on the configuration of the coast and bay and the capacity and direction of its entrance, the flood tide, impressed as it is with the power that moved the tidal wave in the ocean, may, by virtue of its momentum, even run uphill and at the stopping place, at the limits of a bay, attain an elevation higher than obtains near the entrance. We cannot be sure, therefore, that a spirit level line of constant elevation, running around a bay, will give the proper high-water mark everywhere, unless it be checked by tidal observations made at one or more points remote from the place of beginning.

I have included an exhibit of the *intermediate* or so-called "ordinary" tides, remembering a lucid English court decision which stated that to determine ordinary high-water mark, not the spring tides are to be taken, nor the neaps, but the average of the ordinary tides occurring between the two; and to show that in this locality the average of such tides is practically the same as the average of all our tides. With us the springs and neaps are respectively greater and less than the ordinary by practically the same amount, so that their inclusion in determining the averages does not affect the result. Why, then, did not the judge simply say that the *average* of *all* should be taken? Maybe in the locality to be affected by his decision the tides are

different from ours, in that the springs are more in excess than are the neaps in defect of the "ordinary," making their inclusion give a marked difference in the averages; or, maybe, he had his mind not on figures, but on the tides themselves, and plainly said that ordinary high-water mark is not that made by either extreme, spring or neap, but by the average of the intermediates.

The following quotation is from 18 California, page 21, opinion of Justice Field:

> "The limit of the monthly spring tide is, in one sense, the usual high-water mark, for, as often as those tides occur, to that limit the flow extends. But it is not the limit to which we refer when we speak of 'usual' or 'ordinary' high-water mark. By that designation we mean the limit reached by the neap tides. That is, those tides which happen between the full and change of the moon twice in every twenty-four hours."

I had read this decision and it, coming from so able and clear a man, impressed me with the confusion that exists in the matter. Judge Field's own words show that his ideas of tides were erroneous. He says "monthly spring tides," when spring tides are *semi*-monthly. And he uses the word *neap*, not in its technical sense, and in its generally accepted sense as given by lexicographers, but in some ambiguous sense of his own to designate a plurality of tides "between the full and change." Now the neap tide is as distinctive as is the spring, equal in frequency and alternating with it, and being the lower limit of the varying oscillations of the tides as the spring is the upper limit; it is not the "usual" or "ordinary," but is as "unusual" and "extraordinary" as is the spring tide. Justice Field also uses "*change of the moon*," but we are not sure of his meaning, for some apply the term to the passing from the fourth quarter to the first quarter only, that is, to new moon, while others apply it to any passage from one to another of the phases of the moon, of which there are four.

It appears to me that the judge thought that all tides are either spring or neap; that the springs occur but once a month and at time of full moon; and that all other tides are neap tides and differ but little among themselves, making them the "usual" or "ordinary" tides. He judges that the acceptable tides occur "twice in every twenty-four hours," which may indicate that he would take both lower high and higher high water in determining his "ordinary" or mean or average; but since his knowledge of tides was only general and superficial, as just shown, he may not have considered that there is a marked

difference on this coast between the two high waters of the day.

In the '90's I had occasion to make a special study of tides and to analyze a tide record made for several years by a self-recording tide gage, and I was surprised to learn how erroneous had been my former views.

Having explained the general conditions and my individual opinion as to "ordinary high water," I desire to make the following categorical statements to the questions submitted to me:

1. The neap tides are not the intermediates between the springs and the lowest, but are the lowest high waters occurring on or near the dates when the moon is 90 degrees from the sun, or in its quarters, the dates being indicated by the symbols "☾" and "☽" in the tide tables.

2. Justice Field is not correct in saying the "ordinary" high-water mark means the limit reached by the neap tides. The average of the neap tides may be determined from the tide tables, as has been done in this discussion, by selecting and averaging only those smallest predicted tides, occurring twice each lunar month, when the moon is in its quarters. Note that the minimum or neap tides do not always occur exactly on the date of quadrature, but that they are sometimes a day or two earlier or later. This, too, holds good for the maximum or spring tides.

3. There is a neap higher high water and a neap lower high water, as shown heretofore, the former averaging 4.5 ft. and the latter 3.5 ft. above the plane of mean lower low water for La Playa, or 1.6 ft. and 0.6 ft. respectively above mean sea level.

The language of Judge Field conveys the meaning that the average of both higher high and lower high should be taken, for he says tides occurring *twice* in twenty-four hours, and either *alone* occurs but *once* in twenty-four hours, but I doubt that he considered that there is so much difference between the two, and I think I have shown that his understanding of the word "neap" was incorrect.

4. As answered in paragraph 2, the average of the higher high and lower high neap tides may be determined from the tables, as has been done in a preceding paragraph, and the mean of the two taken thus for La Playa: $\frac{3.5+4.5}{2} = 4.0$ ft. above mean lower low water, or $4.0 - 2.9 = 1.1$ ft. above mean sea level. This is lower than the average of *all* high waters,

which at La Playa is 4.8 ft. above mean lower low water, or 4.8—2.9 = 1.9 ft. above mean sea level.

5. If Judge Field meant average of higher high waters of neap tides, it may be determined from the tables, as shown in a preceding paragraph, where the mean is found to be, for La Playa, 4.5 ft. above mean lower low water, or 1.6 ft. above mean sea level.

I read the words of Judge Field, but I am not sure of their meaning, which is inaccurate, for spring tides are oftener than monthly; the language is also conflicting, for the neap tide, which is the minimum, cannot be the "usual" or "ordinary" or average tide.

In view of all I have read, and of my reasoning in the matter, I think *ordinary high-water mark* is not that made by the spring tides, nor that made by the neap tides, but by the ordinary or average of the tides occurring between the two, and that in this locality the elevation of such mark is practically the same whether in determining averages we include all the tides or exclude the springs and the neaps, being at La Playa 4.8 ft. above mean lower low water, or 1.9 ft. above mean sea level, if both the lower high and the higher high waters are to be taken, or 5.5 ft. above mean lower low water, or 2.6 ft. above mean sea level, if only the higher high waters of each twenty-four hours are to be considered.

My own belief is that in this locality "ordinary high-water mark" is at the elevation of the mean of *all* the *higher high* waters, or at 5.5 ft. at La Playa.

My reasons are tedious, but I will give them:

Former court decisions are not valuable as precedents in this case, for those resulting from cases in the East are based on conditions as to tides that are different from the conditions obtaining here; and of the decisions pertaining to this coast, some, at least, show a want of familiarity with the subject and an absence of the knowledge that here the alternate semi-diurnal high waters are so different, their main effort being to show that high-water mark is not that reached by the highest or spring tides.

In New York or Washington the consecutive low waters, as well as the consecutive high waters, differ by so small an amount as compared to the range of tide that little thought is given to the difference, and the average of all low waters is taken as a plane of reference, called *mean low water* by the United States Coast and Geodetic Survey in its hydrographic

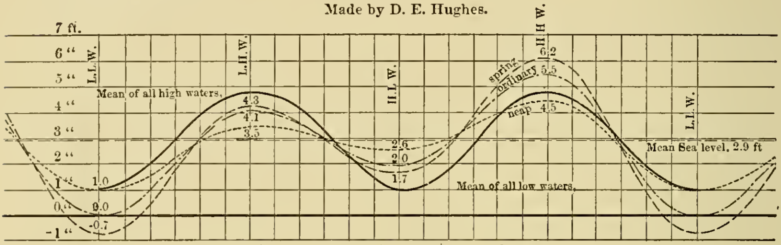
surveys and by the War Department and others in coast and harbor works. Likewise, mean high water is the mean of all high waters.

In California, however, the differences are so great as compared with the range that different departments of the government use the mean of the *lower* low waters as the datum plane, and though it may be, and frequently is, called simply "low water" or "mean low water," *mean lower low water* is understood. Likewise "high water" or "mean high water" is as often understood to be mean higher high water.

Diagram illustrating average tides at La Playa, San Diego, California,

Showing the two consecutive oscillations of the water surface at mean spring tides, mean neap tides, mean of spring and neap tides of the four groups, and the mean of all the high tides and all the low tides for one lunar day.

Made by D. E. Hughes.



	L.L.W.		H.L.W.	L.H.W		H.H.W.	
Mean of all spring tides,	-0.7		1.7	4.3		6.2	shown thus;-
Mean of all neap tides,	1.0		2.6	3.5		4.5	" "
Mean of all tides in a group	0.0		2.0	4.1		5.5	" "
Mean of all high and all low waters.		1.0			4.8		" "
Mean Sea Level.			2.9				

Herewith is a drawing showing graphically the magnitudes and sequence of average spring tides, average neap tides and average of *all* tides at La Playa. Occasionally, even at La Playa, the higher low is about as high as the lower high, and on a few occasions I have seen it even higher. Assume such a day with the tides, say, L.L.W., 1.0; L.H.W., 3.0; H.L.W., 3.0; H.H.W., 5.0. It would hardly seem proper to average the same height, namely, 3.0 ft. with the 1.0 ft. to get low water and with the 5.0 ft. to get high water, giving 2.0 ft. and 4.0 ft. respectively, which latter artificial figures do not represent the possibilities of the day either for launching boats or digging clams; nor its restrictions either on navigation or planting corn.

At St. Michael for about three fourths of each month the water is higher at the point in time corresponding to higher low water than it is at the point in time corresponding to lower high water, so that these two tides drop out, leaving only what elsewhere are the higher high and lower low to occur in each lunar

day. Under such conditions we should be forced to use only the *lower* low for *low* and only the *higher* high for *high*.

In law we must think of the *purpose* of making high-water mark the boundary. Considering navigation, water that is navigable once a day or even less frequently is navigable water, as in the case of certain rivers which can be used only for a part of the year during floods. And, let me say here, that in determining high-water mark for a river we would not include in our average the small rises that might be sandwiched in between the principal ones. These considerations point to the higher high tide as the logical one to adopt.

I think our California courts have interpreted *low-water mark* to mean the average of the lower low waters, for the Coast and Geodetic Survey charts have been taken as evidence of the location of low-water mark, which mark on such charts of our coast is the line of lower low water. We, therefore, require by analogy that high-water mark shall be interpreted to be *higher* high water.

It may be here remarked that any contention for lowering the upper limit of tide land would be expected to apply also to raising the lower limit. Otherwise, one would be seeking to have the limits out of balance with respect to mean sea level, about which the tides oscillate. That is, if we were to have high-water neap tides for one limit, we should have low-water neap tides for the other, which, if we were to take the means of the unequal tides composing the neaps, would be, at La Playa respectively, 4.0 ft. and 1.8 ft. above mean lower low water, or 1.1 ft. above and 1.1 ft. below mean sea level. This would be narrowing the tide lands far below what they were surveyed by the state to be, and extending the high land beyond its limit as generally surveyed by the federal government.

Let the high-water line be run with a level and it, though up to the 5.5-ft. elevation, will be found outside of the limits generally regarded by the people as high-water mark, partly because the impressions on the minds, as well as on the beach, are the results of the higher waters, if not the extremes, and partly because the leveling instrument is indifferent to waves, which impress our minds, as well as our feet, that the high-water mark is higher than it really is. On the ocean shore one may get his feet wet surveying high-water line, even at time of low tide.

Considering navigation further, in most places the maintenance of navigable channels depends on the amount of water

flowing in them, and their capacity is determined, not by the lesser tides, but by the greater ones producing the greater velocity for scour and transportation of material. This again argues in favor of conserving the higher high water to its limits.

Looking at high-water mark from the landsman's view, we must remember that in the times when private ownership began and high-water mark was made the limit of such ownership, land was plentiful without resorting to reclamation, and it made no difference to the husbandman, in rejecting land, whether it was covered with water twice a day or only once; it was unfit for cultivation and thus he would set the higher mark for his boundary. In this connection I may add that in the public land surveys which set the boundaries for private ownership and determined the acreage thereof, any surveys along "high-water line," or "ordinary high-water mark," were made, as a rule, not with the aid of tidal observations and leveling, but by following the "line of drift"; that is, the line at which sea grass and other drift material had lodged. Such line we know is above the limit of the average of even the *higher* high waters, for nothing could be left on a beach by some lower tide that would not be swept higher by a succeeding greater wave.

The general result of advancing seaward, even to the elevation of the average of all the higher high waters, as determined from tidal observations and leveling, is to give to private owners more land than they or their predecessors ever paid for. And any effort to set the boundary mark at still a lower level may be looked upon as the creation of a gift to the individual at the expense of the public.

One may argue, Why restrain an individual from encroaching a few feet upon the ocean waste covering three fourths of the globe? But beyond the mark where nothing has been paid, the rights of the public are paramount to that of the individual. Let the public, not the individual, advance upon the sea if it shall benefit mankind. There are cases where it may seem ungenerous to eject some poor individual just because his land is a foot too low, but the coming San Diego case may lead to a decision which will become a precedent for determining the greatest cases where powerful corporations are endeavoring to control such marginal lands which multitudes of poor men will need for public use in connection with public harbors for the benefit of all.

In conclusion, I hold for the *mean* of all *higher* high water,

which at La Playa is 5.5 ft. above mean lower low water, or 2.6 ft. above mean sea level, as the true *ordinary high-water mark*, to limit private ownership on the shores of an important public harbor.

Fluctuation of the Tides and the Determination Therefrom of the Ordinary High Water at San Diego, Cal.

BY OTTO VON GELDERN.

The writer has read with considerable interest a discussion of the subject of tidal rises in San Diego harbor, written by Mr. D. E. Hughes, the object of which is to establish definitely a plane referred to in common parlance as "ordinary high water."

It will occur to any one who has given this subject any thought that this rather important plane — important in that it fixes a boundary seaward of what may be valuable property holdings — has never been scientifically, that is, clearly defined.

The opinion of Justice Field, quoted from 18 California, page 21, is ambiguous in that it does not fix or define the plane in such a manner that there shall be no doubt hereafter as to what is meant by the term "ordinary high water."

To state that

"By that designation we mean the limit reached by the neap tides, that is, those tides which happen between the full and the change of the moon twice in every twenty-four hours," is to make the subject still more unintelligible, and it becomes evident to any hydraulic engineer that Judge Field had failed to grasp the principles and characteristics that make up the phenomenon of the tide. If he had said the highest of the neap tides, or the mean height of the higher neap tides (for there is a high water large and a high water small in neap tides as well as in spring tides), or if he had stated the mean of all the neap tides, there would have been an understanding and a precedent, but in his ambiguous language there is nothing to guide us, nor anything to define what he did mean. Neap tides are as characteristic as spring tides and occur, speaking generally, half way between them, and not, as Judge Field would have it, "twice in every twenty-four hours between the full moon and the change." The spring tides are a result of the syzygies when combined solar and lunar influences are at their maximum, while the neap tides accompany the quadratures, when these influences oppose each other and are minimized.

The diurnal inequality of the tides is a characteristic of our coast which does not prevail everywhere. This peculiarity

gives rise to two unequal high waters and two unequal low waters on the same day. The terms "high water" and "low water" do not, therefore, convey an exact meaning. After the lower low water of the day the tide rises to the lesser high water; then follows the small run-out to higher low water, which may amount to only 1 ft. or even less; this is succeeded by the higher high water, which secondary rise is frequently not over 18 in.; it is followed by the great run-out of the day, involving a rapid and uninterrupted ebb flow to the lower low stage. These inequalities are more pronounced as the moon reaches its maximum declination either north or south, and they disappear when it is on the equator, a matter that will be referred to again.

To a hydraulic engineer it is simple enough to take all the tidal data of a harbor, to tabulate them and to show how high all the higher high spring tides and all the lower high spring tides and all the higher high neap tides and likewise all the lower high neap tides have been in reference to some datum plane during a lunation, or during a lunar cycle even; to average them and to give their mean rises and ranges, but in a legal sense this has just prepared the way and does not lead us a single step nearer to the definition of the term "ordinary high water."

The spring floods may be termed extraordinary high waters, or maximum stages, while the lower high waters of the neap tides are corresponding minimum stages and in that sense just as extraordinary. The ordinary high water lies somewhere between these two; and to determine *that somewhere*, upon some sound reasoning and in some manner commensurate with the legal and economic and social conditions which it is to meet, that is, to fulfill the spirit and intent of the law in dealing with a practical condition of life, is much more difficult than it may at first appear.

The highest high spring tide in the harbor of San Diego is 6.9 ft. above the reference plane, and the smallest high water of the neaps, that is, the lowest high water known at all, is 2.8; if these two values are of equal weight, and if the intermediate tides occur with equal frequency, we may assume the ordinary high water as half way between these extremes, or at 4.85 ft. above the plane of reference. This reasoning appears perfectly logical, but whether it is correct to take this position may depend upon the meaning of the adjective "ordinary." If by "ordinary" we mean "more frequently," the determination of the plane will depend upon the frequency with which certain

high tidal stages occur and recur in reference to other stages that are not as frequent and not as often observed and impressed upon the mind.

Mr. Hughes has gone through all the labor of tabulating tidal heights, of grouping them and drawing averages, the results of which cannot be disputed. They are absolutely accurate; there is no question as to that. The summary of average results as determined by him is as follows:

Average of All Tides at La Playa for a Number of Years, as Given by the United States Coast and Geodetic Survey.

Lower low water	0.0	1.00
Higher low water	2.0	
Lesser high water	4.1	4.8
Higher high water	5.5	

While there is no question as to these values, the final determination of 5.5 ft. as the elevation of the *ordinary high-water plane* is, however, an arbitrary individual assumption, no matter how logical Mr. Hughes may be in his reasoning upon the premises that lead him to adopt this height. There is no doubt that the rise of 5.5 ft. represents the mean of the higher high waters of each twenty-four hours, which is naturally the same as the mean of the higher stages occurring between the syzygies and the quadratures, that is, at the octants, which Mr. Hughes calls ordinary high water.

All this is quite interesting and paves the way to a final agreement of what shall constitute ordinary high-water plane. The term *agreement* is used advisedly, for there cannot be such a thing as a *solution* of the problem.

The adoption of 5.5 ft. as the height of this plane above the harbor datum is likely to create a difference of opinion among hydraulic engineers, and the writer has no doubt that the question will be raised whether the ordinary high-water plane ought to be assumed at this elevation. Plausible reasons may be given why it should be something else.

In the opinion of the writer the plane is too high. It seems to him that an "ordinary high water" which is but 1 ft. lower than the average of the thirteen greatest monthly tides does not deserve the adjective *ordinary.* If we glance through the high tides of one lunation we shall find that in period of frequency the heights range between 3 and 4 ft. To be sure, these are principally the high waters small of each twenty-four hours and in that they fail to convey the idea of "ordinary" as something

between the higher stages and the lower stages of high water. It behooves us, therefore, to agree upon some intermediate plane which will satisfy the human impression of frequency of occurrence; that is, this tide must not be too far away from the limit of the plain man's conception of it, who has no knowledge of the flood factors, and whose sole impression is that made by the demarcation of the water line on the beach. By accumulative evidence he obtains a pretty clear idea of the limits of an ordinary high tide.

Acknowledging the extreme difficulty of fixing any definite plane in a constantly fluctuating series, it seems to the writer to be more logical to take the mean of all the high waters and not the mean of the higher high waters; that is, referring to Mr. Hughes' table:

Mean of all high waters........................	5.5
Mean of all low high waters....................	4.1
	9.6
Ordinary high water...........................	4.8

That it is practically the same as the mean between the highest high and lowest high, as brought out heretofore, is due to the fact that the groups between the mean and either extreme are equal in frequency and gradual in variation, a sequence which is quite natural if we come to think of it. The plane assumed at 4.8 ft. above datum appeals to the writer as more rational than any other. In determining it we give equal weight to all high waters, whether large or small, whether spring or neap.

There is another method by which we may attempt to deduce this particular plane. A very important flood factor with us is the moon's declination, upon which the daily inequalities of the tides depend. As stated before, the two high waters and the two low waters of the same day tend to balance each other as to height when the moon is in the equator, and their differences become more and more pronounced as the declination increases towards its maximum either north or south. The amount of declination is variable and differs on the average as much as 10° 16′ within a lunar cycle of 18.6 years. The mean angle which the moon's orbit makes with the ecliptic is 5° 8′, and on account of the regression of the nodes its inclination to the equator will vary from 28° 36′, the maximum, when the moon's ascending node coincides with the vernal equinox, to the minimum of 18° 20′, at the expiration of half of the lunar cycle (nine and one-quarter years after that), when this node is in the

autumnal equinox. We have, therefore, a variation of range in declination from 57° 12′ in the months of the maximum year to one of 36° 40′ in those of the minimum year of the same cycle.

These extremes are not without their influence upon the tides of the temperate zones, those that obtain on the Pacific coast of the United States, for instance, which are modified in turn by the occurrences of the apogees and perigees; that is, different combinations of flood factors produce differing results, and it is mainly for this reason that no tidal data are complete unless they involve the observations and deductions of the various combinations of these factors which are possible within a full lunar cycle of about nineteen years.

Tables have been published by the United States Coast and Geodetic Survey that give average results due to lunar declination for a number of tidal stations on the Pacific coast. That for La Playa is here given to show the relations as determined for this locality.

Moon's Declination.	Moon's Upper Meridian Passage.				Moon's Lower Meridian Passage.			
	High water.		Low water.		High water.		Low water.	
	Interval.	Height.	Interval.	Height.	Interval.	Height.	Interval.	Height.
	H. M.	Feet.	H. M.	Feet.	H. M.	Feet.	H. M.	Feet.
Greatest north..	8.53	5.6	16.16	—0.3	10.23	3.7	14.58	2.1
Zero...........	9.28	4.9	15.40	0.7	9.28	4.9	15.40	0.7
Greatest south..	10.23	3.7	14.58	2.1	8.53	5.6	16.16	—0.3

This table is of the "Coast Pilot" of 1889. In explanation of this table it may be said that the time interval, which does not concern us so much, is for the purpose of predicting the time of the tide and is to be added to the time of the moon's meridian passage, which is taken from an almanac. The heights show the rise above the plane of the mean of the lower low waters, and the instructions for using these heights are:

"Spring Tides. — At the full and change of the moon the high waters will be seven tenths of a foot higher than the above and the low waters seven tenths of a foot lower.

"Neap Tides. — At the moon's first and last quarters the high waters will be seven tenths of a foot lower than given in the above table and the lower water will not fall as low by seven tenths of a foot."

The table, therefore, depicts average tidal conditions as caused by the moon's declination which may be corrected for syzygies and quadratures. For zero declination, when the moon is on the equator, the tabular values are those of the mean of the averages, as it were, when the high-water large equals the high-water small and the low-water large, the low-water small. The high stage at this period represents an average between the spring and the neap tides, and in this sense it may be ordinary high water. In the table before us this is 4.9. Taking an average of all the diurnally even high waters given in the tide table for the year 1908 results in a height of 4.8.

To sum up the results of this discussion, the writer is of the opinion that the plane of "ordinary high water" is readily described as the average of all high waters, no matter whether large or small, and that this on our coast will agree, or nearly so, with the mean high water occurring at or near the day when the moon crosses the equator, that is, when the two tides of the same day are equal in height. No stress is laid on the latter deduction; the weight of the writer's argument lies in the average of all, irrespective of occurrence.

If the writer is accused that in this adoption he is just as arbitrary as Mr. Hughes, he will not be able to make any defense, for the reason that the result cannot be obtained by deduction, but that it must be agreed upon first and described subsequently. It is like the determination of a bench-mark which was placed first to suit the conditions and located afterwards.

The writer is convinced that for practical purposes the plane recommended by Mr. Hughes is too high, and that if such a line (5.5 ft. above the datum) were actually laid out and staked off permanently on a sheltered beach the eye would behold on many occasions during each lunar month a strip or margin of land below such a line which on a nearly level marsh may be many hundreds of feet wide; and the question would arise again and again from an abutting owner, "Why is this large strip of land, which is so very frequently exposed to sun and air, and needless for harbor purposes, not mine and why may I not make use of it?" The ordinary high water impresses itself to be much below. On a steep shore there never will be any controversy, but on an almost level marsh, where six inches difference in tide involve large areas of land, the difficulty will arise again and again until some precedent has been established.

The writer endorses all the arguments made by Mr. Hughes in his paper, but he differs from him in the final adoption of the

plane and he believes that the ordinary high water of law, commerce, navigation, ownership and for cadastral purposes should be that of all the high tides rather than that of the higher series alone. Nor is he unsupported by others in the position here maintained.

After this paper was written, the author applied to the superintendent of the United States Coast and Geodetic Survey for a definition of "ordinary high water" as interpreted by the experts of the Survey relating to the establishment as here suggested, and requesting any information that may throw light on the subject. The reply received stated that the Survey had not defined "ordinary high water" on the Pacific coast.

"The topographic work is referred to the plane of mean high water, which, in practice, is often obtained from marks on the shore. And while the definition of average high water when the moon's declination is zero and the diurnal inequality has vanished is allowable, it differs so slightly from the mean of all high waters in this case that the superintendent expressed a preference for the latter definition. The mean of all high waters is easy to obtain and seems to conform more closely to the meaning of the word 'ordinary.'"

Another definition is given by W. H. Wheeler, M. Inst. C. E., in his "Practical Manual of Tides and Waves" (1906), page 70:

"MEAN HIGH WATER.

"The mean level of high water at any given part of the coast is the *average height to which both spring and neap tides rise* on the shore as ascertained over a lengthened period.

"This level is of importance, as it determines the limit of the rights of the Crown to the foreshore, beds of rivers and the tidal creeks as against frontagers, all foreshores below mean high water being claimed by the Crown or Duchy of Lancaster, except where the right has been alienated by special grants.

"Although there is very considerable difference in the height to which the tides rise at different parts of the coast of the world, this variation consists in a depression below and elevation above a fixed point, the mean level remaining the same whether the tides rise 40 to 50 ft., as in some places, or only 1 to 2 ft., as in others." . . .

"From investigations of six years' tides (1833–1838) taken at Plymouth under the superintendence of Mr. Walker, the Queen's Harbor Master, made by Airy, it appeared that the level of mean high water is constant from year to year within 2 or 3 in.

"At the head of the Bay of Fundy spring tides rise 45 ft., while in Northumberland Straits, which is separated from the

bay by a narrow neck of land 18 miles wide, the range of spring tides is only 9 ft. From levels taken across this neck of land for the Chicnecto Ship Railway it was ascertained that the mean level of the sea is only 3 in. higher at Baie Verte, in the Gulf of St. Lawrence, than in the Bay of Fundy."

The average of all the high waters, therefore, seems to have been preferred in the deduction of mean or ordinary high water; its very simplicity in definition pleads for it.

In the upper reaches of our bays and inlets the plane produced by averaging all high waters, large as well as small, will be a more reasonable deduction than any other, because the tides there will rise much higher. Thus on the Suisun marshes the high water rises 1.2 ft. higher than at San Francisco, while the low water is from 0.1 to 0.2 of a foot higher only, and the unusual high level of the "ordinary high water," if assumed on the basis of the mean of all the higher high waters to the exclusion of the lesser high, even if but 1 ft. or 9 in. or 6 in higher, will become a very important consideration for those who may in some measure depend upon it. Large areas of our valuable marshes will become useless. It is, therefore, not practicable, nor even possible, to establish this plane for an entire harbor with a surveyor's level, but certain reaches at assumed distances must be independently treated and connected with each other by tidal observations, as Mr. Hughes has already pointed out.

The accurate establishment of the plane in accordance with whatever base the court may adopt as official is not a simple matter of surveying, but it involves a rather careful study of the harbor by qualified engineers, and it will require time and labor to define it.

The writer has an intimate knowledge of San Diego harbor, having surveyed in detail its approaches, bar, outer channels and interior waterways as far as National City, and studied its tides and tidal characteristics from the outer bar to the interior marshes, or he would not have entered into this discussion as minutely as he did.

Concluding, he suggests the adoption of the mean of all the high waters, whether spring or neap, large or small, which at La Playa is 4.8 ft. above the mean of the lower low waters, or 1.9 ft. above mean sea level, as the *ordinary high*-water plane, which plane practically agrees, in this harbor, with the mean of all the diurnally equal high waters when the moon has zero declination.

Discussion.

By Mr. Hughes.

It is a matter of much satisfaction to me that Mr. Von Geldern agrees that *ordinary* or *mean* high water is not the high water of neap tide, which is as *extraordinary* as is the *spring* tide, but that it is the average of a large number of tides, no matter whether including *springs* and *neaps*, or excluding them, since practically the same average will result.

Our difference of opinion is only as to whether the higher high waters occurring daily shall be averaged, as is my contention, or whether the lower high waters, where and when they occur, shall be included, howsoever small their rise above mean sea level may be, thus making the semi-diurnal tides determine the result, as is his opinion.

His assertion that an *ordinary high water* which is only 1 ft. lower than the average of the thirteen greatest monthly tides does not deserve the adjective "ordinary" does not appeal very strongly to me, for the *one foot* will appear small or large only in comparison with the range of tide; for instance, large on the Atlantic end of the Panama Canal and small on the Pacific end, where the tides are several times as great.

In speaking of the spring tides we always have in mind only the higher high waters averaging 6.5 ft., and not the lower high stages occurring on the same days and averaging only 4.5 ft. Analogy requires that in speaking of ordinary high water we should think of the mean of the daily higher high waters only.

The idea that the 4.8-ft. plane should be adopted for La Playa because it gives equal weight to *all* high waters, whether large or small, used to appeal to me, too. But in determining high-water mark of a river we do not include the lesser intermediate rises. In tide water we could not always include a daily lower high water if we wanted to, for it does not always exist everywhere, being absent occasionally, as at Galveston, and absent three fourths of the time, as at St. Michael.

At La Playa the daily higher rises average 5.5—2.9 or 2.6 ft. above mean sea level, while the lower rises are but 4.1—2.9 or 1.2 ft. above the same plane, and the 2.6-ft. level now appeals more strongly to me than would either the 1.2 ft. or any imaginary non-existent compromise mark between the two, for it more than any lower plane determines the capacity for navigation and for maintenance of channels by tidal scour, as well as the limitations of the field of ordinary husbandry.

The higher plane is nearer to, though still below, the lines as generally surveyed in the past to mark the boundary of a bay.

If in law we must try to think, not of figures, but of a material, visual mark on the shore made by the tide, then we again exclude the lower high water, for any mark that it may make is obliterated by the higher tide which follows. The sighing swain went daily to the beach to write upon its syrtic tablet his message of love, a sisyphean labor, which caused him to cry in desperation: "I'll pluck one of Norway's tallest pines and dip it in the burning crater of Ætna, and across the azure skies I'll write, 'Marinda, I love thee!' Now I'd like to see any perfidious tide wash that out!" Any enduring visible "high-water mark" on the shore is even higher than the elevation of 5.5 for which I contend.

To make the tides that occur at the time of the equatorial position of the moon a gage for an average plane may appeal to many. Since inequalities of semi-diurnal tides depend so largely in our latitude on the declination of the moon, it is very natural to think of more nearly equal tides which occur when the moon is in the equator as giving an indication of the height to be adopted for "mean high water"; and there is given from the "Coast Pilot" of 1889 (subject to possible later correction) 4.9 for this height, and from the tide table for the particular year of 1908, 4.8; and Mr. Von Geldern points to this as a confirmation that his 4.8 and not my 5.5 is the proper elevation for "ordinary high-water mark"; he frames the result of his discussion to be that the plane of "ordinary high water" is the average of all high waters occurring at or near the day when the moon crosses the equator, when the two tides of the same day are equal in height.

I am sure that further thought will remove the value placed on this discovery that the 4.8 or 4.9 is equal to the 4.8 elevation for which he contends, for the equality is only a coincidence.

In the first place, the two tides which occur on the days when the moon crosses the equator are in general *not* equal. My computations for those days, twenty-six in number, for the year 1908 make the lower high water at La Playa average 4.8 and the higher highs 5.3 ft. The difference is due to the fact that not all the daily inequality is due to the declination of the moon. A portion of it is due to the declination of the sun, whose tide-producing effect is three eighths of that of the moon, and to follow the above line of reasoning we should have to

accept only those days when the sun as well as the moon is in the equator. There are still other though smaller sources of inequality which, were we to regard them all, would leave us but few tides in 18.6-years' time free from cause of inequality.

But the greater error is in drawing *any* conclusion from the near equality between the tides at La Playa when the moon is in the equator and the mean of all high waters, or the 4.8 ft. I need only point out that this approximate equality is merely a coincidence resulting from our particular latitude. If we were at the equator we should have the summits of both the direct and opposite lunar tides at our door on the days when the moon is crossing the equator, and their average would be much higher than the average of all high waters of the month or year, and higher than the average of all higher high waters. If we were in high latitude, as St. Michael, our average of tides when the moon is crossing the equator would be decidedly lower than the average of all tides.

It is also stated that if my 5.5-ft. line were staked off, the abutting owner may ask, "Why is that strip beyond, which is so frequently exposed to sun and air and needless for harbor purposes, not mine?" I would answer: "You already have more than was originally surveyed and assigned to you, and no man knoweth the limit of future harbor needs. This strip on the shore of the people's harbor shall be protected from private greed and forever conserved for the public good." If the abutting owner be not a clam digger nor a harbor grabber, but a tiller of the soil, he will be surprised to see the line of stakes so far outside of where the gophers bore.

In conclusion, I rejoice that my friend has agreed with me so well, and I am thankful that he has so fully given his impressions and arguments for the little difference of opinion that remained, and I trust we have a court big enough to ignore meaningless precedents and wise enough to render a decision to stand the test of reason and of time; and I hold more strongly than before that "ordinary high-water mark" is at the level of the average of all daily higher high waters, which at La Playa is 5.5 ft. above the plane of reference, or 2.6 ft. above the mean level of the sea.

Reply.

BY MR. VON GELDERN.

Referring to the statements made by Mr. Hughes, the writer wishes to emphasize that he places the main weight of

his definition of ordinary high water upon the average of all high waters during the course of a year or number of years. He is of the opinion that this definition gives a plane easily established for any harbor and one that will meet all the requirements for navigation and for the treatment of the foreshore. It needs no better definition.

To define it as the mean of the high waters when the moon is in the equator has been mentioned as secondary only, and it is agreed that for a legal definition it would not serve. Nor is it necessary to make reference to it. But it may still be of sufficient interest to follow the matter for a few moments, if only to inquire whether on the Pacific coast of the United States there is a great divergence from this deduction. Let us make the application to harbors located at the extreme ends of the coast.

It will be admitted that the inequalities do not disappear exactly on the day of the moon's equatorial position; the diurnal equality may precede or follow this occurrence by several days, according to the influence of other combinations of flood factors. This is quite true, as Mr. Hughes points out. If, however, those high waters are chosen from the table which are diurnally equal, irrespective of their coincidence with the moon's zero declination, or with the diurnally equal low waters, say, for the period of one year; if they are added together and divided by their number, a result will be obtained which is not far from the average of all the high waters for that year. While this statement is unimportant, it is interesting.

Take the harbor of San Francisco, for instance. A tabulation of tidal data relating to this harbor, and deduced at the Washington office from observations at the Presidio station, extending from 1898 to 1905, gives the following results:

Mean of higher high waters............	5.8 ft.	above the plane of mean lower low water.
Mean of the lesser high waters.........	4.6 ft.	
Mean of all high waters...............	5.2 ft.	

Taking from the published tide tables for 1909 those high waters only that are diurnally equal, we obtain:

Mean of the high spring tides	5.6 ft.	above the plane of mean lower low water.
Mean of the high neap tides..........	4.6 ft.	
Mean of all high waters..............	5.1 ft.	

That is, the average of the diurnally equal high waters checks within one tenth of the mean of all the high waters, and it is quite probable that it would agree with it better still if the means were based upon eight years' records instead of one.

The writer made it a point to confer with the city engineer of San Francisco to ascertain the plane of ordinary high water as interpreted for the harbor and sewer work, and he received the following information from Mr. Marsden Manson:

	Ft.
Reading of the city base on the Coast Survey staff................	17.35
Mean of the lower low waters of the bay........................	5.51
City base above plane of mean lower low waters................	11.84

Ordinary high water is about 5.14 feet above the plane of mean lower low water.

This determination practically agrees with the other two.

Mr. Hughes' plane of ordinary high water exceeds the writer's by six tenths of a foot in this case.

This comparison was extended and applied to the harbors of Astoria, Port Townsend and Sitka with similar results.

In the case of any harbor where pronounced diurnal inequality in regular sequence exists at all, the average of all the high waters and of all the low waters will represent tides of the same level for the same day. That is, there is then but one height for high water and one height for low water, and the result of this final average of all highs and all lows is a constantly equal high and a constantly equal low water for a period of any length.

But let it be understood that there is no need of this additional confirmation, if confirmation it be. It is much simpler to define this plane by the statement that ordinary high water is the mean of all the high waters of some period of sufficient length without having recourse to any method of lunar or solar demonstration. The writer knows the difficulty accompanying theories. The scientific treatment of a practical subject is fraught with danger, and a proof based upon an interpretation of statistical data, no matter with how much erudition it may be rendered, should not be assumed as convincing unless the statistical data are overwhelmingly in its favor. To say that an increase of the inner diameter of the doughnut without any corresponding addition to its outer diameter is a mathematical proof of an advance in the price of foodstuffs is quite interesting, but it does not carry the conviction of an absolute demonstration. It may be so, to be sure, but there may have been something the matter with the baker during the conception of the doughnut. Only an overwhelming number of doughnuts, from innumerable localities, showing the same micrometric discrepancies will justify such a conclusion.

To make a direct statement again, Mr. Hughes' plane is too high.

As a practical illustration, the two planes were made applicable to a locality with which the writer is very familiar, that is, the Alviso Marsh, south and west of the Coyote River, at the extreme end of the southern part of San Francisco Bay. The mean of the higher high waters here is 8.6 ft. above the plane of mean lower low water and the mean of all the high waters, 7.9; the difference is seven tenths of a foot. The general elevation of the floor of the marsh is 8.0 and does not vary greatly from this for several miles south of the outflow of the Coyote River; to establish the foreshore at an elevation of 8.6 would leave a gap between the river bank and this boundary of many thousand acres, rendering useless an expanse of bottom land of great value when properly reclaimed, which, by the way, is absolutely worthless as a part of the tidal estuary.

It seems to the writer that the main consideration should be to so fix this boundary that it shall not render useless the valuable marsh lands which, from the earliest civilization, have been brought under cultivation for the benefit of man. European countries bear testimony to this and may serve as examples.

Final Remarks.

BY MR. HUGHES.

In several localities in California, old Spanish or Mexican grants bounded upon a bay, and the United States, in confirming and patenting the grants, passed into private ownership all that was proprietary in character, leaving nothing to be ceded to the state under the Act of 1851. And, in general, except in sheltered localities, the lands which correspond in elevation to salt-marsh, namely, those between ordinary and extreme high-water marks, are too narrow to have received separate consideration and have been patented with abutting higher lands by the United States to individuals, leaving again no proprietary land to pass to the state. Hence, throughout the greater portion of our coast the "ordinary high-water mark" is a partition line between lands patented by the United States on one side and the shore on the other. And one, in forming a definition of *ordinary high-water mark* for general application should think not only of spirit level and figures, but also of the higher mark followed by the public land surveys, and think not only of the individual of the day, but of the enduring public as

well, which considerations would lead one to adopt the highest level that reason can sustain. Old maps are not to be entirely disregarded in favor of our leveling and figuring.

If instead of mean lower low water as a datum, we refer our heights of tide to the more natural datum of mean sea level, above and below which the waters oscillate, the difference between the principal diurnal tides and the smaller intermediate tides become more pronounced, accentuating any reasons for omitting the alternate little tides in making averages for practical use. Thus, the lower high of 4.0 ft. and the higher high of 5.5 ft. at La Playa, the one appearing as 73 per cent. of the other and, therefore, of seeming importance, become, when referred to mean sea level, respectively, 1.1 ft. and 2.6 ft., which give the true proportions of the amplitudes of the two tides. Now the little tide is only 42 per cent. of the principal one and would be less unwillingly, if not more hastily, rejected than would it when appearing as 73 per cent. For illustration, assume a shore 100 ft. wide covered and uncovered daily by the tide; if the rising tide halts to give an intermediate vibration covering and uncovering only the middle 42 ft. of the 100 ft., must we say the shore is only 71 ft. wide? If so, then at St. Michael, where the rising tide three fourths of the time does not stop to uncover anything until it has reached its full height, shall we average the nothing with the one hundred, and thus by figuring make the shore only half of what we see?

The adoption of the mean of all the daily principal tides, disregarding the smaller fluctuations which do not always intervene, would make a rule of universal application.

Mr. Von Geldern, in his first discussion, sums up with the opinion "that ordinary high water is the average of *all* high waters and that this on our coast will agree, or nearly so, with the mean high waters occurring at or near the day when the moon crosses the equator, that is, when the two tides of the same day are equal in height."

Of course such near agreement does not obtain near the equator, where such tides are then higher than the mean of the higher high waters, nor in high latitudes, where they are then lower than the mean of all, and is in our latitude a mere coincidence on which Mr. Von Geldern lays but little stress. Yet in his supplementary discussion he pursues the thought further as a matter of interest and makes comparisons for San Francisco, Astoria, etc. But the exhibits made are not clearly consistent with the former suggestion, for now he speaks of

tides that are diurnally (not semi-diurnally) equal, and gives for such tides in San Francisco Bay 5.6 ft. for the mean of the higher highs and 4.6 ft. for the mean of the lower highs, which is very different from having "the two tides of the same day equal in height."

Simplicity is also suggested in favor of accepting the mean of *all* high waters as against the mean of only the higher highs, but it does not appear how it is simpler to observe two high waters per day instead of one.

At St. Michael the lower high water and the higher low are absent three fourths of the time and one would be forced to observe only a diurnal high water corresponding to our higher high in California. Then during the remaining one fourth of the time, and in lower latitudes, during longer proportions of the time, when the intermediate tides of comparatively small amplitude become sandwiched in, they should not be included in determining averages of either high water or low water, for they affect neither commerce nor husbandry, and their inclusion would give results misleading to both fisherman and farmer.

In localities which I have observed there is a marked difference between the straight sea grass on sheltered tide land and the crinkled salt grass on the marsh land and the change occurs at an elevation corresponding better with the mean of the higher high waters than with the mean of all the highs.

After our principal discussion was written, the engineer for the San Diego Harbor Commission located and marked the 4.8-ft. contour on the shore, and all, including himself, were much surprised to see it so far out in the bay. Even the 5.5-ft. contour is outside of what is the average plain man's conception of ordinary high-water mark.

The fraction of a foot between us may mean much to some area which the public will never need at the limits of so large a harbor as San Francisco Bay, but it may mean more in a smaller harbor where it is more clearly the duty of the state to conserve all and fulfill its trust to generations yet unborn.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1910, for publication in a subsequent number of the JOURNAL.]

PUBLIC SANITARY STATION AT BROOKLINE.

By Alexis H. French, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, October 6, 1909.]

This structure was built during 1909 and is located on public land in Village Square, through which several lines of street cars to and from Boston pass at the rate of one per minute in both directions during the rush hours. It is also located in the most densely settled part of the town, at the junction of several main avenues on which there is much teaming. The location would, therefore, seem to be as nearly ideal as anything of the sort could be in a town of about 27 000 population.

The details of the design are shown on the accompanying plan, by which it will be noted that a room 15 ft. by 18.5 ft. in dimensions, with six water closets, six urinals, two lavatories and a bubble drinking fountain is devoted to men, and a room of the same size containing six water closets, two lavatories, a bubble drinking fountain and a small retiring room is designed for women.

The structure is built of Portland cement concrete mixed in the proportion of 1 : $2\frac{1}{2}$: 5, reinforced as shown on the drawing. The floor on the men's side is placed 9 ft. below the walk, the ceiling is 8.5 ft. high and the roof covered with from 2 to 3 ft. of loam, the entrances and grading so designed as to render the sanitary as inconspicuous as possible. It will be noted that the entrances are designed with covered vestibules and right-angle turns in the staircases, thus securing the maximum of privacy. The ground over and adjoining the sanitary has been planted with shrubbery.

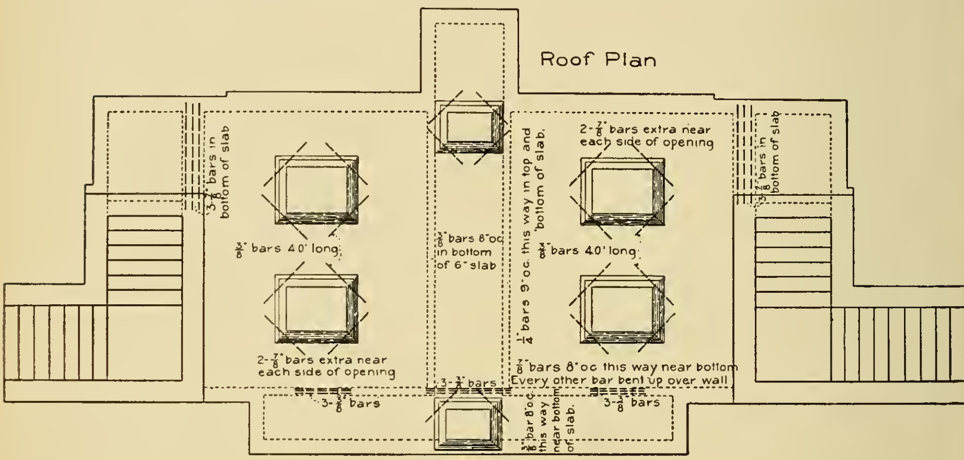
The sanitary is well lighted during the day with six light shafts arranged as shown, in which are placed $2\frac{3}{4}$ in. luxfer prism sidewalk lights spaced 4 in. on centers. During dull weather and at night it is lighted by electric lights controlled by suitably arranged switches.

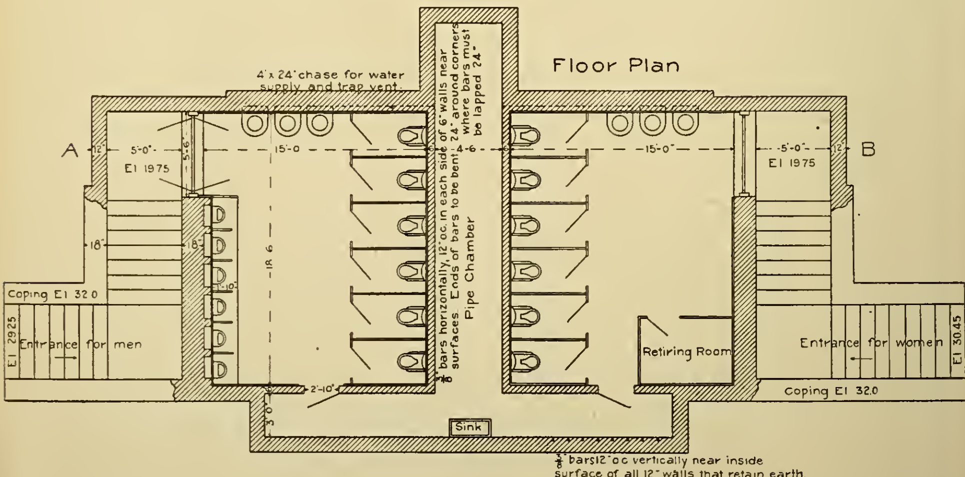
The roof and walls are waterproofed by the application of a heavy coat of roofer's pitch and also with five layers of roofer's felt combined with hot pitch for a distance of 2 ft. below the roof and by the use of three layers of felt to a level of 4 ft. below

the roof. No special precaution was taken to waterproof the bottom, as the level of ground water was much below that elevation.

On account of its non-absorbent character and freedom from stain, the gray Tennessee marble was used for the water closet partitions, urinal stalls and wainscoting, the height being 6½ ft. in the case of the water closets and 6 ft. elsewhere. White vitreous 3-in. by 3-in. by ½ in. tiles were used in the main rooms on account of their non-absorbent character and great durability.

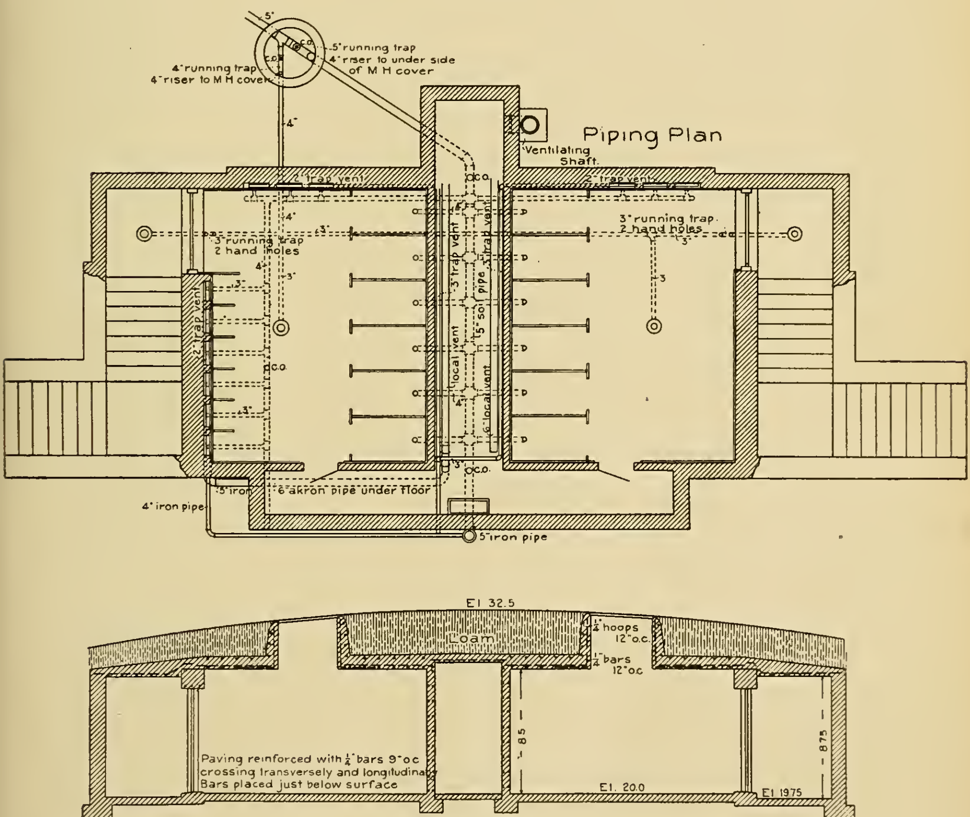
A feature of the design which it is expected will work well in operation is the pipe chamber and passageway, in which are





located the main soil pipe with its branches and cleanouts, the trap ventilation, water closet tanks and connections, ventilating fan and conduits, slop sink and space for the storage of supplies. Such pipes as are placed below the floor of the main rooms are made accessible by cleanouts with brass cleanout screws.

Brass floor drainers are placed in the vestibules and in the center of each main room, with waste pipes connected with the main drain below the main trap in the manhole, so that a stoppage of this trap will not cause the sewage to set back into the sanitary.



Section A-B

Plan of a Public Sanitary
Brookline, Mass.
1909.

Alexis H. French
Town Engineer.

The type of water closet adopted is the "Sanitas Keystone," for the men's side, and the "Sanitas Keystone Hygic," for the women's side, both designed and made by the Sanitas Manufacturing Company, of Boston. They are siphon jet closets and are especially well adapted for a public sanitary because of the form of the bowl and its rim, and the unusually large water area. The exterior of the closet is commendable from its simplicity and in that it does away with the space behind the bowl which too often serves as a hiding place for dirt. The closet is also provided with an unusually large local vent.

The water closets are so designed that each closet contains only a bowl and a push-button device for operating the tank in the adjoining pipe chamber, thus securing the maximum of simplicity and ease in obtaining cleanliness.

The urinals are also of the siphon jet pattern, made by the same company, and are substantially the same pattern that has been satisfactorily used at the South Terminal Station in Boston for ten years, modified to meet modern plumbing requirements. These also have a large local vent connected with a copper ventilation pipe placed in the wall behind the urinals and leading to the ventilating fan.

A system of ventilation has been adopted, but not yet installed, consisting of an electrically operated fan to be placed in the pipe chamber near the ventilation shaft, with ducts leading to each closet and urinal, so that the air in the sanitary can be exhausted through these fixtures at the rate of once in fifteen minutes. It is believed that this will be ample to keep the air good under the worst weather conditions.

The building is heated from the hot-water system in the fire station plant, only 10 to 15 ft. away, and is designed on the basis of 1 sq. ft. of radiation for each 40 cu. ft. space to be warmed. In addition to this, a 9-ft. radiator is placed in each light shaft to aid in the warming and to keep the snow melted in winter.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1910, for publication in a subsequent number of the JOURNAL.]

PUBLIC SANITARY STATION AT LAWRENCE..

By Arthur D. Marble, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, October 6, 1909.]

For a good many years the city of Lawrence had maintained a public urinal in the basement of the City Hall, directly under the office of the city treasurer. It was difficult to keep the place in decent condition, and there was more or less controversy as to what department of the city government was responsible for its care. The place naturally was especially offensive in summer when the windows of the offices above had to be open; and finally the city closed it up and purchased two sheet-iron urinals of the same pattern as the one that was located on Boston Common near the Boylston Street entrance to the subway. The park department also had a urinal erected on the playstead; this was built of cast-iron sheets, and was supposed to be more or less ornamental, but the boys soon smashed it, and the remains had to be carted away to the dump. After the two sheet-iron urinals were purchased, the problem was where to put them. No one wanted such a structure near his place of business, so the city council finally disposed of them in the vicinity of two freight yards near the heart of the business section of the city, and they have probably served their purpose fairly well.

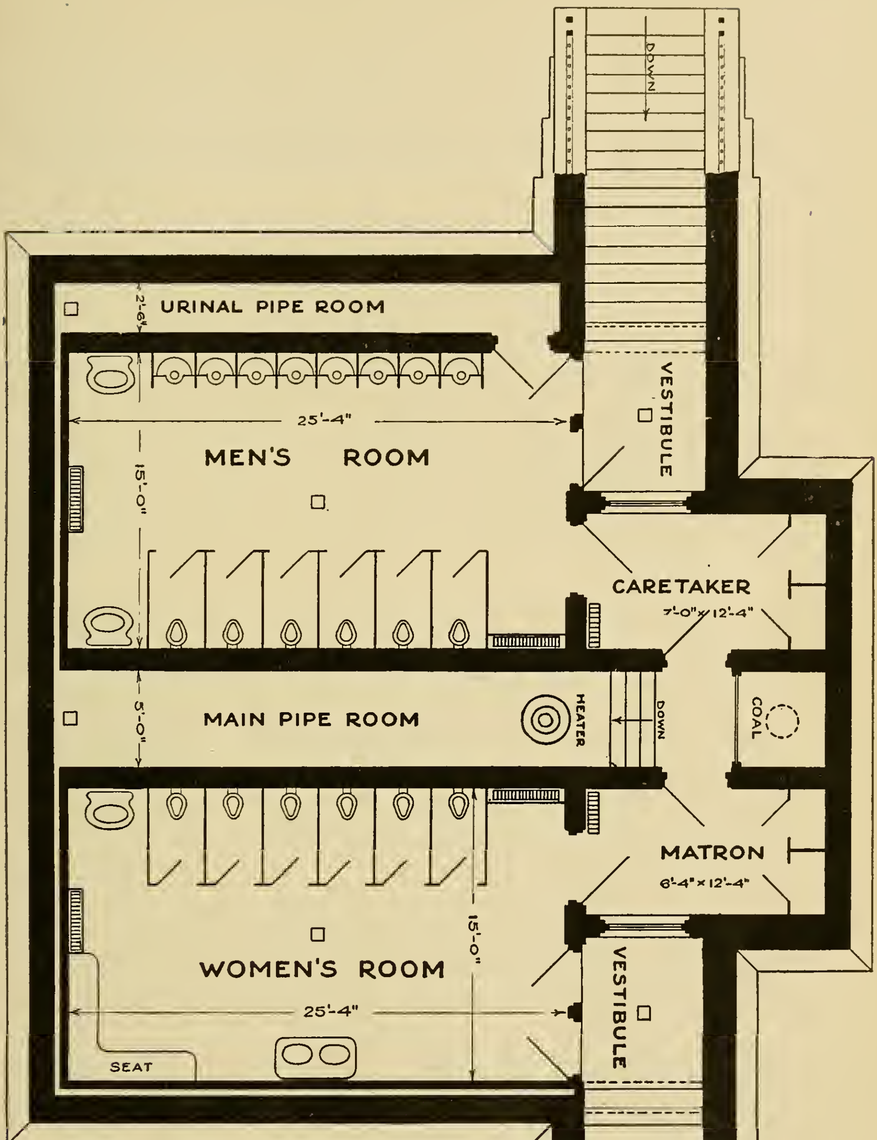
These urinals, however, only in a small degree satisfied the public demand. The women had not been considered in their installation, and they had to depend on the large stores, the railroad and the transfer stations for toilet conveniences. These places are usually so dirty and offensive that few women care to resort to them. Possibly Lawrence is an exception to the general rule, but I have heard otherwise.

For a long time agitation for a public station for both sexes had been carried on in our city, and in 1907 its construction was made possible by a vote of the city council authorizing the park commission to spend $12 000 for what the order termed a "comfort station," and the city engineer was directed to prepare plans for it.

Considerable opposition to its construction developed after the order appropriating the funds was passed, especially when the yearly expense of running it was considered, which expense would amount to considerably more than half of the usual appropriation for the maintenance of our public parks. There are probably now many prominent citizens who, if they expressed their opinions, would be opposed to its continuance. One man, a would-be mayor, told me he would make a swimming pool of it if ever he had a chance; and another, an ex-mayor, said he would fill it in if he should happen to again occupy the mayor's chair. He had an idea that no decent woman would visit it. I told him that it was not used much by the so-called foreigners, but that nicely dressed women, apparently of the English-speaking races, used the station largely, and it was with a good deal of pleasure that we could refute the charge that only foreigners would use it, and say that it was really a convenience station to all classes of our citizens. The attendants tell me that the women's side is used by a better class than the men's. I mention these things to show that no matter how good a piece of work may be, how much it may be needed, or how economically it may be carried out, there is always adverse criticism if the public has to foot the bills, and I presume these conditions prevail not alone in Lawrence, but are common to most municipalities. The station in Lawrence was opened to the public on December 30, 1907, and within a week it was estimated that between five and six hundred persons used the station daily. On special days and Sundays the place is visited by four or five thousand on each side, and its necessity and value have been proven beyond the possibility of contradiction.

The attendants examine every closet after it has been used, and the station now is in as perfect condition as when first constructed. Not a dollar has been expended on repairs, and no plumber has been called in to remove any obstructions or remedy any defects.

The interior of the building was made as white and as spotless as possible, so that no dirt could exist there without being plainly seen. The interior walls are of brick, and all exposed surfaces are built of white enameled brick, with a base of three courses of chocolate-colored enameled brick. The closet bowls are set in the usual open plumbing style; the urinals are of solid porcelain, and run to the floor, so that the smallest boy can use them properly; the water closet and urinal partitions are of white Italian marble, said to be harder and less absorbent



FLOOR PLAN OF
PUBLIC CONVENIENCE STATION
CITY OF LAWRENCE - MASS.
DESIGNED BY ENGINEERING DEPT.

SCALE OF FEET
1 5 10

SCALE OF METERS
0 1 2 3

than any marble quarried in this country; the floors are of terrazzo, made of bits of stone embedded in cement, the prevailing color being white, with a neat mosaic border, all on a foundation of concrete; the ceiling is of concrete, painted white with one coat of "Bay State Brick and Cement Coating" followed by a coat of "Enamel" of the same brand. It would have been better to have put on two coats of the first, as the ceiling did not come out quite as white as was desired.

The main toilet rooms are lighted by day by two skylights in each, 3 by 4 ft. in size, and at night by electric lights enclosed in Holophane globes. The effect of the whole is bright, fresh and clean. The electric lights are divided into five circuits which are regulated from a switchboard in the main pipe room. These circuits are men's room and light at foot of stairs; women's room and light at foot of stairs; the transparency on men's side; the transparency on the women's side, and the attendants' room and pipe room.

The station has also a "Gamewell Police Signal Box," which serves as a call box for the officer on that beat during the hours the station is open. This box connects only with the police station and, aside from that, the station has no telephone.

The general plan of the station includes the two main toilet rooms, about 15 by 25 ft. in size with a 9-ft. post. Each of these rooms contains six water closets. In addition to the closets, the women's room has three lavatories and also a long seat built against the wall. The closet slips are 2 ft. 10 in. by 4 ft. 10 in. in size from center to center of the marble partitions. The men's room has two lavatories and eight urinals. The two radiators in each of the toilet rooms are enclosed in white marble, with white porcelain enameled registers to allow the circulation of the air. A man would not be likely to try to spit through the registers and he certainly cannot spit behind the radiators.

In addition to the main toilet rooms there are two attendants' rooms and two pipe rooms. The main pipe room, 5 ft. wide, with its floor grade 3 ft. below that of the toilet rooms, runs through the center of the structure. This main pipe room should have been at least a foot wider, for unless the plumber utilizes every inch of width, as he did not in our case, and carefully sets the heaters, there will hardly be room enough for a man to get by the large heater into the space beyond. In this main pipe room are all the pipes, flush tanks and vents connected with the water closets, together with a Gurney heater, which in the winter heats the rooms and the water for the lava-


WOMEN

tories; also a small jacket heater for heating water and maintaining ventilation in summer. The small heater is run continuously all summer and burns two tons of coal. A total of about 8 tons of coal is used in both heaters for the year. Directly in front of the heaters (the door from the attendants' room opening between the two) is the coal bin, with a capacity of 6 tons. The bin is fed through a coalhole in the roof. On the side of the men's room back of the urinals is another pipe room, with its floor 2 ft. below that of the toilet room, in which are located the flush tanks and piping for the line of urinals. There are four flush tanks in this room, one for each two urinals, and they discharge automatically at intervals of about two minutes.

The ventilation of the station is secured entirely through the water closet seat vents, which are about 13 sq. in. in sectional area and pass through the wall back of the closets to the main galvanized iron vent pipe, which is connected with a cylinder that surrounds the smokestack and reaches the open air near the top of the copper ventilator that stands on the roof of the station and extends to a height of about 15 ft. above the ground.

The seats of the closets are of wood, entirely cut away in front. We at first thought of having a porcelain seat, but they were said to be very unpleasant to sit on, so we adopted the kind described.

The attendants' rooms are 7 by 12 ft. in size, with a quartered oak wardrobe filling the entire width at one end. These rooms are large enough for one or two chairs and also a couch, which we thought might be needed in case of any sudden illness. These rooms furnish a convenient place for the attendant to sit apart from the general toilet room, and is so located as to command a view of nearly that entire room. There is a door leading into the pipe room from both attendants' rooms, so that in case of a disturbance on the women's side the male attendant can be called in without his having to pass around on the outside. With the door locked on the women's side, the protection for that side is as perfect as though there was no door there. The attendants' rooms are ventilated each by a window hinged at the bottom, opening into the stairway landing. The men attendants, of course, do the heavy work, caring for the heating apparatus, taking out the ashes and shoveling snow in winter. They receive $14 for a week of seven days. The women receive $10.50 for a week of the same length. Both the male and female attendants keep the brass work polished on their respective sides.

The structure was built underground so as not to disfigure

the Common, and also to avoid the expense of exterior architectural ornamentation. Nothing appears above ground except the copper-covered ventilator and smokestack, which is rather ornamental, and the stone parapets with the wrought-iron fences which enclose the entrance stairways. Over each entrance is a wrought-iron arch carrying a transparency bearing on one the word "men," and on the other, "women." These transparencies show milk-white glass letters by day and are illuminated at night.

The outside walls of the structure are built of concrete and the roof is a flat slab of reinforced concrete, both walls and roof being covered with Warren Brothers waterproofing material. As the walls are lined with brick inside, an air space was left between the outer and inner walls, and this air space would probably have kept the interior walls dry without any waterproofing. The excavation was somewhat wet as we neared the floor grade, and two broken stone drains were laid across under each toilet room floor, terminating in an open pipe laid through the wall into the main pipe room. The main pipe room is drained of ground or surface water into the trap of the main drain. With these drains, and the bed of cinders under the concrete floors, no dampness ever shows on the terrazzo. To further protect the walls against dampness they were backed up with cinders.

The interior of the station can be washed out with a hose, if desired, and the floors are drained into a cesspool in the center of each toilet room, and in the landing at the foot of the stairs. The last-named cesspool also takes the rain water which finds its way down the stairs.

In addition to the conveniences sure to be found in such a station, paper and liquid soap are furnished free of charge. The paper is delivered from two Springfield paper holders in each toilet room. The paper used costs about $7 per month, and the soap about $25 per year. A roller towel was at first hung up in each toilet room and nickel-plated rollers were attached to the walls for them to run on. Of course they never should have been even thought of, but the Park Commission were impressed with the idea that the popular demand required them. However, they were soon discarded as unsanitary, and the material was cut up into individual towels, and given to the attendants, who take care of them and let them out for a cent each. The attendants have the proceeds. After this toweling is worn out it is intended to let the attendants furnish and care for the

towels and have, as now, what they make out of them, the Park Commission regulating the price charged for their use.

One closet on the men's side is reserved as a pay closet, but it does not amount to very much. In the first four months after the station was opened this closet was used but once. A charge of 5 cents is made for the use of this closet, and this charge includes a towel. The men's side of the station is open from 7.30 in the morning to 11.30 at night, and the women's from 8 to 11. Two men and two women are employed as caretakers, and the annual expense for maintenance is about $3 200.

Bids were received for building the convenience station ranging from $9 776 to $15 324; bids for plumbing, heating and marble work, from $2 997 to $3 933; and for electrical work, from $160 to $317.

The totals of the actual cost were as follows:

C. E. Trumbull Company, contract for general building work,	$9 776 00
Extras	234.38
Merrimack Supply Company, plumbing, etc., heating and marble work	2 997.00
Extras	71.73
Geo. D. Fitts, electrical work	160.00
Inspector	312.00
Water Department, piping	43.97
Blue prints	47.86
Police Signal Box	150.00
Incidentals	104.89
	$13 897.83

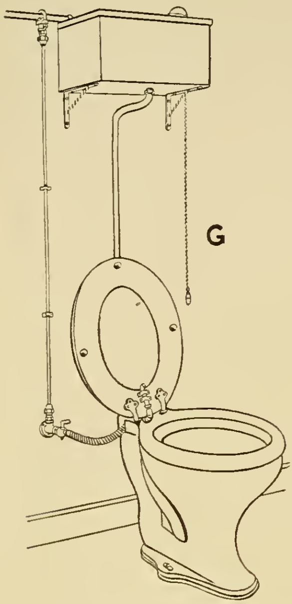
DISCUSSION.

Mr. Humphries. — Among the new designs of devices for the promotion of personal cleanliness and sanitation is the KleenSprā Bidet.

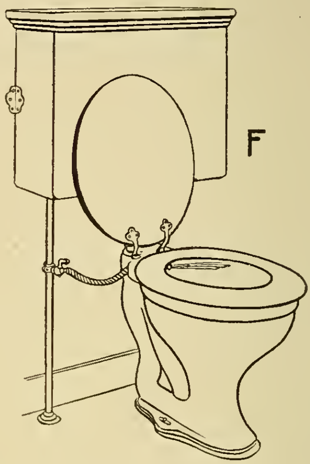
This bidet is a radical departure from former designs, inasmuch as it can be attached in a few minutes to any toilet seat by means of a screwdriver and a drill. This simplicity of construction naturally brings the price so low that the manufacturers expect to make the use of bidets universal.

The device consists of a valve so constructed that it can be easily clamped to any water pipe (usually the tank or basin supply); a spraying tip which is placed at the back of the seat underneath; and a flexible metallic connecting tube to connect the valve with the spray tip. The parts are either nickeled or constructed of non-corrosive metals.

Cut G shows the standard KleenSprā. Cut F shows the bidet with the water turned on, throwing its concentrated jet forward and up. The KleenSprā is also made in a portable



G



F

fixture which can be used in connection with the bathtub or basin faucet. This fixture can be snapped on or off the seat in a moment's time.

Although the KleenSprā Bidet is only a few months old, the users' recommendations seem to be that it is surprisingly efficient and does not spatter or unnecessarily wet.

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1910, for publication in a subsequent number of the JOURNAL.]

THE ECONOMY RESULTING FROM THE USE OF THE LEVEL ON THE FARM.

By George M. Lewis, Member of the Montana Society of Engineers.

[Read before the Society at its Twenty-third Annual Meeting, Butte, Mont., January 8, 1910.]

At no time has farming required the application of thoughtful intelligence for successful results as to-day. The work of our state agricultural colleges, and especially our Department of Agriculture, has forced the respect of the business and financial world for the producer of crops. Their annual condition, yields, prices and movement determine the prosperity of all raw product transformers, the balance sheets of the railroads, also that mythical balance of trade margin, with its resulting freeness of the money market, and hence the investing power and consumption capacity of the people. In fact, upon the extent of this yearly generosity of old mother earth depends all other branches of business activities for the ensuing twelve months. Earth yields of her crops only as a proportionate reward of man's effort.

No phase of agriculture brings more immediate reward or apparent results from the otherwise non-producing soil than irrigation, where the highest intelligence in planning and studiousness in working out are used. Let us pass the canal construction stage and take the irrigated farm as it is so often found, with water delivered to the ranch and already applied for some years. As with other beneficial things, misuse sometimes leads to unlooked-for bad results. Improper handling of water, either in manner or quantity, will produce in a few years with normal conditions either a swamping or alkalizing of the lower drainage territories, or both. As a result of such misuse, we see many instances of each and combinations of both in our own Gallatin Valley, one of the richest and oldest irrigated districts of the state.

The farmers of the Gallatin Valley have until recently had access to abundance of water, more than they could properly use, with the result that large areas of the heaviest, best and oldest occupied lands were becoming swamped, and, in some places, alkali was showing more plainly and becoming more

troublesome each year. The farmers had become educated to the idea that they must have this abundance to irrigate their crops. There resulted a most peculiar condition as, later, canals were taken out. With more than enough water to cover this irrigated area, there was still a shortage at the critical season each year. This condition occasioned the largest water suit in point of parties involved that has ever been tried in this or any other country. The decree adjudicating all these rights was signed last September by Judge Cheadle, of Lewistown, the presiding judge. His judgments were so fair and so carefully determined, as shown by the findings, that the decision in this case will prove, as time goes on, one of the greatest benefits to the district affected. Water will now have to be used economically and not, as heretofore, with such extravagance as to prove a detriment to lower lying lands.

The brains and guide of all tools on the irrigated farm should be the little Gurley. It plans the most efficient application of water, economizes its use and prevents these harmful results.

The very climatic conditions of intense evaporation which necessitate irrigation will act as well to distill from the water where not properly controlled and deposit in the soil these harmful alkaline salts, which it carries either from its original source of supply or has leached from the soil it has but previously so beneficially saturated.

In planning the irrigation of each field the wise use and control of water must be kept in mind. Strongly sloping fields and hillsides are easily handled by terracing grade ditches, knolls can be covered with the country fall, depressions likewise drained. Here the head taken out progressively from the upper source of supply will sweep the fields in a wide sheet of water as it collects, backs at the dams and again spreads from each succeeding lateral. Here the lowest grade can be used to handle the waste and not only keep it from impounding in the first available pocket, there to be wastefully evaporated, and to harmfully leave its resulting additional deposit of Na_2Co_3 (black alkali) or Na_2So_4 (white alkali), but it may be thence carried to some lower ridge and there allowed to spread.

Our soil at Manhattan is classed as Gallatin fine sandy silt. It is the most susceptible of erosion and the slowest of saturation of any in our state. In comparative tests made last summer on the Manhattan farm, it required 7.65 in. of water for a complete saturation. Such soil will stand a maxi-

mum grade in distributing laterals of 0.3 per cent. To do this, however, the laterals must be properly made.

The ordinary road grader is the best ditching tool we have. It makes a wide, shallow, flat-bottomed ditch of good capacity, where the water is easily lifted out for spreading, of small depth, hence, little water weight for erosion, and is easily crossed with bullrakes and other machinery. Such a grade and ditch will carry an abundant quantity of water, and so, differently from the trust-to-the-eye-and-providence ditch, will carry it uniformly. As the carrying power of water varies as the cube of its velocity, a lack of uniformity in grade is much exaggerated in corresponding scouring at each acceleration and filling with sediment at each checking of flow. Nothing will so quickly lessen the capacity of a ditch in a few short hours, because field water is so heavily laden with silt.

It is on flat land with little country fall that most care is required in planning the ditching system. The general fall must be studied, all knolls and ridges noted, especially if isolated, and a skeleton planned to cover such high points, keeping the supply ditch always available for tapping. Isolated knolls or ridges must be levied to. If above the commanding grade, they must be contoured and shaved with the Fresno, carrying the dirt in a neck to the point to be tapped for the water supply. If not too high and the depression between not too deep, a fill can be made in this way and the ditch run thereon. It is hardly practicable to shave a knoll more than 12 to 18 in., not on account of expense, for the work once performed is good for all time, but because beyond this limit you usually get below your growing soil depth.

With a Fresno we have moved dirt in such way on the Manhattan farm at a cost of 5 cents per cubic yard. Flat land always shows numerous such knolls and corresponding depressions, when you get the level on it, which are hard to handle on account of country fall. Here each depression must be tapped and the water led off and spread again. Standing pools of water with the hot sun's rays soon scald out the growing grain in summer and freeze out the alfalfa in winter. The dandelions then get started and flourish in such places. The irrigating farmer has no more baneful weed than this with which to contend.

We have ditched a field north of Manhattan containing 125 acres with 13 grade ditches, the lay of the land happening to be such that the field fell with the grade. Water turned in at the upper end was repeatedly utilized and, as the work reached

the lower parts of the field, was gathered as it accumulated and used beyond. This field has been watered at a cost varying from 70 to 78 cents per acre. Formerly the ditches were run with the eye, as is the customary way; they were necessarily extravagant of grade, of shorter broken lengths and of less capacity. They numbered 70. Under these conditions it used to cost $1 to $1.10 per acre to irrigate. As this cost is entirely a labor item, it seems that it took 50 per cent. more time with the same volume of water. In figuring for economy, we thus have a right to presume that while we are cutting down cost 50 per cent. we are increasing the duty of that water 50 per cent. also. With water worth $3 per acre, this is no small item.

About seventy-five acres per day can be planned and run. During the past season we have thus ditched 1 000 acres of crop land on the Manhattan farm. We do not use stakes, as it is too cumbersome and slow to carry the necessary supply. We equip a good walker with an irrigating shovel to accompany the rod man. At each station of 50 ft. he mounds up two shovelfuls of earth. His day is not an easy one, as it is a constant exertion for him to keep up with the rod man. These mounds are more easily seen than stakes by the men following with the ditching machinery.

With the high price of labor commanded by our irrigators, the growing necessity to increase the efficiency of water and the care which must be used to get no bad results with the great good derived, the foregoing suggestions may not come amiss.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1910, for publication in a subsequent number of the JOURNAL.]

PAINT FOR IRON AND STEEL.

By Frank Neal.

[Read before the Detroit Engineering Society, February 18, 1910.]

Iron and steel paints have been the subject of some scientific study by both the consumer and paint manufacturer, but I am inclined at times to believe that very little is actually known yet as to what really is the best coating for iron. Without trying to review all the scientific work that has been done along this line, with which you are doubtless familiar, I will try to give you briefly some results of our own practical experience as paint manufacturers.

The old claim that linseed oil is the life of paint does not necessarily apply when we are considering iron coating. While linseed oil is a necessary ingredient, other elements are equally important, namely, the pigment to be used and some other vehicle to offset certain characteristics of the oil. In painting on wood we have a more or less absorbent surface, depending on the wood that is used, but on iron the paint has no absorbing surface into which the oil can penetrate and bind. The oil must make its own bond in such a way as to form a thin, even coating not easily marred or scraped off. This cannot be done by the use of linseed oil alone. I have in mind the specification of a large railroad in this country that was drawn up by a very eminent chemist. The pigment was composed of 45 per cent. carbonate of lead and 55 per cent. pure carbon lampblack, and the vehicle was composed of about 90 per cent. linseed oil balance dryer. The specification called for not in excess of 15 per cent. pigment and 85 per cent. vehicle in the total. This paint was designed for use on steel freight cars. You know what extréme conditions these cars are submitted to and what the paint must stand if it has any protective value. Now I have made quite a number of carloads of this paint and naturally wished to know what it would do, so I made tests and, while this paint costs the railroad company about $1 per gallon, I have tested it against different paints which they could buy for not in excess of 75 cents per gallon that have proven vastly superior to it.

On several occasions I have gone into large buildings in

course of construction for the purpose of examining the steel which was being erected and have found it coated with a film of oil paint which under a slight pressure of the finger could be shoved completely off the surface. Such paint is totally unfit for the purpose for which it is designed. I have often wondered that a great many more fatal accidents do not occur, owing to the slippery condition of this paint film under the feet of the man, sometimes many stories up in the air and mighty little between him and his Maker if he slip on this kind of paint. I wish to impress upon you that in buying paint for structural work great care should be exercised in selecting an article that will produce a film that will be firm under the feet of the man that you send away up in the air to erect the steel.

At Atlantic City the Society for Testing Materials is conducting a series of tests in connection with the United States government and the Paint Manufacturers' Association. These tests, while of importance, are not of much commercial value, for they are all made with practically one binding liquid and that raw linseed oil. It seems to me that in order to get results of practical value we must experiment not only on what pigment shall be used, but what vehicle or combination of vehicles, together with what pigments, produce the best paint for iron or steel.

About twelve years ago we had erected at our factory a large steel tank for linseed oil storage. At that time great claims were being made for graphite as a steel protective coating. Not very much was known at that time about painting iron, and we knew as little as any one else. It was decided to paint the tank with graphite, which was done, but it was black and all our buildings at that time were white. So in order to make it look right we put on three coats of white over the graphite. The following year we erected another tank of the same kind. When it came time to paint it we examined the old tank and were greatly surprised to find innumerable small blisters all over it which, when punctured, were found to be full of water, and the tank was very badly pitted. In order to save the tank it was necessary to remove every bit of that paint and clean the surface of rust, which was done at once. Then the problem of paint again arose. Another pigment had been discovered which was said to be a very fine preservative. This article was made up into paint of the accepted form and applied to the new tank. As a comparison we used for the old tank a mixture of red lead, linseed oil and turpentine. Before deciding on the proportions

of this last formula, I made several experiments to determine just how much oil red lead would solidify. After determining this I found that something more was needed as a thinner. I decided, however, not to add more oil for a thinner, as would ordinarily be done. I decided that the thinner, to make a paint suitable for spreading, should be one that would evaporate, leaving the lead and oil to form their natural chemical compound, which is a cement almost as impervious to water as a combination of litharge and glycerine. This paint we applied to our old tank and then both tanks were coated with three coats of white to conform to our buildings. Since that time we have erected several other tanks, and in every case they have been coated with this red lead paint. The old tank which has been painted now over ten years was in good shape four years ago. We repainted it and all of our buildings, changing the color from white to brown, on account of the smoke which is so prevalent in Detroit where life is worth living. It is still in good shape. On the other hand, our second tank was found to be in bad condition four years ago, and we had to remove all the old paint. While the paint on this second tank had been on for seven years, the undercoat was still an imperfect, undried film, and easily peeled off to the iron as described above.

Now, gentlemen, I do not wish you to get the impression that I think red lead is the only pigment for the protection of iron. The combination which I have described, unless protected by another pigment and more oil, will not stand up at all well as a final coat. When properly protected, however, it will be found to give excellent results. Neither do I wish you to get a wrong impression as to my attitude regarding the use of linseed oil as a protective coating for iron. Linseed oil is one of our best friends in the paint trade as a vehicle or distributer of pigment for its protective qualities and as a binder of the pigment to the surface to which it is being applied. But there is such a thing as getting too much linseed oil on iron, and when we do the end we have in view is defeated and we have an improper combination which the slightest bruise knocks off, exposing our iron to the ravages of the elements. Linseed oil under proper conditions will absorb oxygen from the air or from pigments with which it is mixed, forming a practically insoluble compound linoxin. If this linoxin has a sufficient amount of insoluble pigments in with it, we have something which, while not everlasting, is fairly satisfactory.

Now let us go a step further on the subject of linseed oil.

This article, as it comes on the market to-day, seldom if ever has a chance to settle and age. As a result it is bound to have more or less soluble glutinous matter in its composition, which remains in it and goes into the paint, thus weakening the paint film to a greater or lesser extent. On the other hand, the progressive manufacturer takes a well-clarified oil and by the use of chemicals and heat all of these impurities are driven off and he has left only the valuable part of the oil which, when combined with proper pigments, produces a paint which is very much less susceptible to the ravages of the elements than the raw oil similarly combined.

I have known many cases where an oil, prepared as I have described, and thinned with one half of that much-despised naphtha, has outworn the pure, raw linseed oil, both being mixed with the same amount and kind of pigment. Then, again, we have had good success in painting iron and steel with paint into which different proportions of hard fossil gums have been incorporated. We have also had some little success in the use of resin oil in connection with linseed oil, but only to a limited extent. So we always return to our oldest friend, linseed oil, whether it be in the raw form of commerce or scientifically treated. Without a doubt it stands supreme to date when properly handled.

And now, gentlemen, to sum it all up, the best iron and steel paint I have been able to produce or have seen consists of linseed oil in connection with almost any pigment, providing enough volatile liquid is used to prevent the application of too much oil on to a non-absorbent surface. The point is that too much oil skins over on the surface so that the oil cannot absorb enough oxygen from the air to enable it to become that almost insoluble compound linoxin. Our experience has been and is to-day that in the painting of anything the oil, properly handled, restricted or supplemented where necessary, is the life of the paint. On certain woods too much oil cannot be used in the priming coat. On other wood the more oil used the worse the result. Some wood contains sap or resin to such an extent that it repels the oil, causing it all to lie upon the surface, forming no bond, and when aftercoats are applied which are less elastic, owing to their having more pigment in their composition, the expansion under heat or contraction from cold will cause this paint to peel or crack badly.

Painting on iron is somewhat similar to painting on sappy or resinous wood. In order to get satisfactory results the least

possible amount of oil should be used in the priming coat, gradually increasing the percentage of oil and decreasing the percentage of pigment in succeeding coats, absolutely the reverse of what you would do were you painting white pine.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1910, for publication in a subsequent number of the JOURNAL.]

Association
of
Engineering Societies.

Organized 1881.

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TYNGS ISLAND BRIDGE OF THE VESPER COUNTRY CLUB, LOWELL, MASS.

By James W. Thomas,
Member American Society of Mechanical Engineers.

[Read before the Boston Society of Civil Engineers, December 15, 1909.]

The Vesper Country Club's country house is situated on Tyngs Island in the Merrimack River, a few miles above Lowell. The island is on the easterly side of the river, separated from the mainland on the east by a small creek and on the west by the main body of the Merrimack River. The railway and the trolley are on the westerly bank of the river, making a passage of the main body of the river necessary to all persons arriving this way.

For some years the club operated a hand ferry, but this means of crossing was slow and very unsatisfactory, as it could be used only a few months in the year; service had to be entirely discontinued during the high water in the spring and fall and during the winter months.

The club members have for some years agitated the matter of a bridge across the Merrimack to the island, but no satisfactory designs had been secured. In the fall of 1907 the matter was again taken up and a design, submitted by Westinghouse, Church, Kerr & Co., of New York, accepted. This design called for a suspension foot bridge with a roadway approximately 4 ft. 6 in. wide in the clear and a span 550 ft. center to center of towers, with a 100-ft. trestle approach on the island side and a shorter approach on the mainland side. Fig. 1 shows the stairway approach on the mainland side; this was afterwards changed to a

short trestle landing at the level of the railroad tracks. On the mainland side, the cables pass over the two tracks of the Boston & Maine Railway.

In the design of the bridge the following conditions had to be met:

The center of the bridge should under no conditions be below elevation 107.5, which is about 22 ft. above normal water level, this elevation representing the clearance of another bridge farther up stream.

That the cables on the mainland side should be not less than 22 ft. 6 in. above the westerly rail of the Boston & Maine Railroad, and that the bridge should support a live load of 150 lb. per linear foot.

With this loading, the dead weight of the structure is as follows:

Cables and hangers, 20 lb. per linear foot.

Bridge structure, 120 lb. per linear foot, making the total loading, dead and live, 290 lb. per linear foot. This gives a maximum stress in the cables of 142 500 lb.

The main cables are $2\frac{3}{8}$ in. in diameter, with a rated breaking strain of 232 tons. From results of tests made of the wire used in the manufacture of the cable, we believe the actual strength of the cables is equal to, if not greater than, the above figure, thus giving a factor of safety in the main cables of $3\frac{1}{4}$ under the assumed maximum load.

The suspender rods supporting the structure were attached to the cables every 20 ft. At the center of the bridge, where the cables are lower than the roadway, the bridge is carried directly by blocking on the cables.

The original design called for two guy lines 70 ft. from either side of the center of the bridge. There was also provided a system of lateral bracing of $\frac{1}{2}$-in. galvanized steel strand, laced upon the carrying members, as indicated on the plan. It was found that the central portion of the bridge between the guy lines had very little lateral vibration, but that between the guy lines and the towers there was considerable lateral movement when a number of people were on the bridge at once. This was very evidently due, not to any vibration in the cables, but to the swinging of the suspender rods. After the completion of the bridge, it was thought desirable to increase the number of suspender rods next to the towers. This was done largely with the hope of reducing the lateral swinging of the bridge near the ends, and an additional guy line was attached about half way between

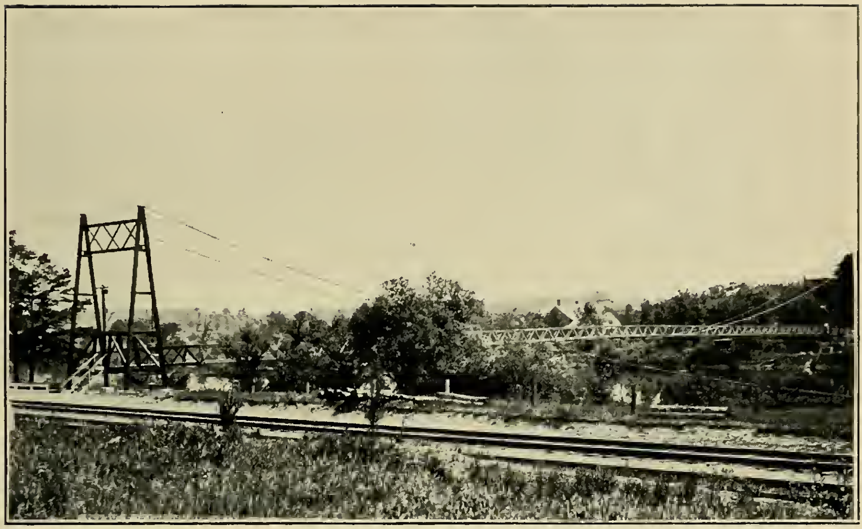


FIG. 1.

FIG. 2.

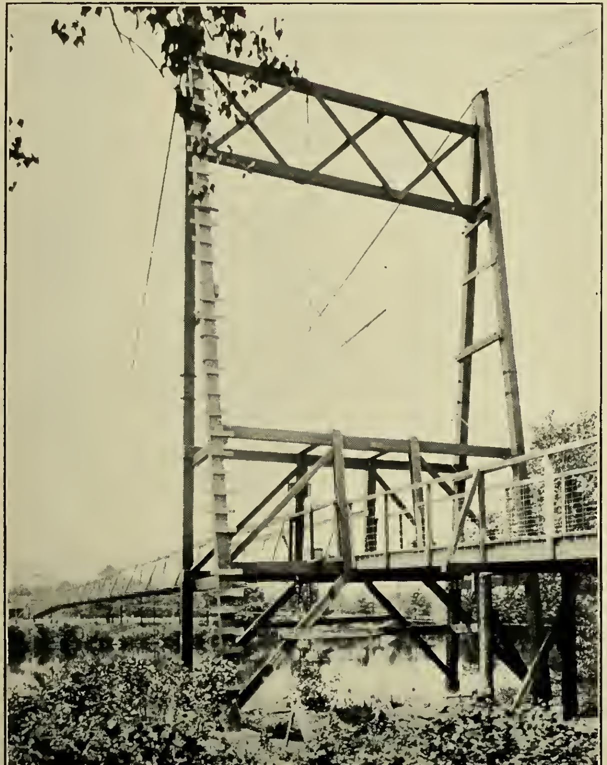


FIG. 3.

FIG. 4.

the towers and the original guys. This reduced the movement considerably and gives fairly satisfactory results.

The cables are cradled from 24 ft. at the towers to 6 ft. at the center of the bridge, being held in place by ties as indicated. With a very high wind blowing up or down stream there is what we might term a "temporary set" in the bridge, the maximum noticed being about 4 in. from the true line, this being the only movement of the cables which has been observed. An interesting feature is the effect of temperature on the cables. The drop of the cables being only about 36½ ft. for a span of 550 ft., a very slight change in length makes a very perceptible change in the elevation of the center, 5 degrees change in temperature making a difference in elevation of 1 in. As the cables are subject to a temperature range from zero in winter to 120 degrees with the sun directly on them in the summer, it is evident that the center of the bridge is subject to a change of elevation of about 2 ft. This required special attention, as the bridge is lowest in summer, when the clearance is needed for the one steamer which uses the river. This steamer was the cause of a great deal of trouble. The Merrimack is dammed for the power development of the Locks and Canals Company at Lowell, a few miles below the bridge, and it is owing to this dam that the river is navigable even for small boats. This steamer, or rather its captain, some years ago succeeded in getting the war department to classify this part of the Merrimack as navigable interstate waters, which made it necessary before the bridge could be constructed to have a special Act of Congress passed and to obtain the consent of the War Department. After much working of the political machinery by the Bridge Committee of the club, the necessary permission was obtained, but not until our construction department had been threatened with the entire land and naval forces of the United States.

Towers. — The towers are of the good old saw-horse type, the one on the mainland being 45 ft. high and the one on the island being 51 ft. high, built of long-leaf yellow pine. The leg timbers are 10 in. by 10 in. each being spliced with a ship-lap splice, and the joints being well bolted and banded. The cross and sway bracing is shown very clearly on Figs. 1 and 3. The lower cross bracing is designed to be the landing of the roadway. The connection between the bridge structure and the towers is a horizontal bearing only for the bottom members of the trusses, and the whole structure is free to move along the axis of the bridge as the change in elevation may require.

All joints in the tower are securely bolted, and all cut surfaces are carefully painted, on completion of the woodwork being given two heavy coats of creosote paint.

The saddles for the cable were special castings made to fit the tops of the timber legs and carry the cables. After the bridge was completed, a galvanized iron hood was placed over each cap to keep out the weather. The foundations for the towers are concrete piers 2 ft. 9 in. square and extending about 4 ft. below the surface of the ground. Each leg of the tower rests on a $\frac{1}{2}$-in. plate and is held in place by "U" irons cast in the concrete and bolted through the timber.

Cables. — The cables are $2\frac{3}{8}$ in. in diameter each, 876 ft. 9 in. long, and are composed of six strands made of crucible steel with a wire core, the cable having a rated breaking strain of 232 tons. On the ends of the cables are attached, by the usual lead joint, cast steel blocks, each block having two $2\frac{1}{2}$-in. holes on $10\frac{3}{8}$-in. centers for attachment to the anchorages.

Anchorages. — The anchorages were the subject of a great deal of study; the ordinary dead-weight anchorages were out of the question because of cost. After careful examination of the ground, it was decided to use a concrete slab 9 ft. wide, 8 ft. deep, 2 and $2\frac{1}{2}$ ft. thick, reinforced vertically by ten $\frac{3}{4}$-in. square bars, the load being distributed horizontally by two 12-in. $31\frac{1}{2}$-lb. I-beams, which also form the attachment for the anchorage rods; all the metal underground being completely encased in concrete. This size of slab gives a pressure against the earth under assumed maximum load of a little less than one ton per square foot. The ground being very good, a trench of the required size was excavated, the iron put in place and then filled with concrete, no sheet piling being necessary. The concrete around the anchorage rods was not put in until the cables were attached and had load on them. The anchorage rods where they went through the anchorage slab itself were encased with 4-in. gas pipe to allow of slight movements of the rod in adjusting the cables without bringing a strain on the concrete. When the load was on the cables, the ends of the rods were raised about $\frac{1}{2}$ in. and the concrete put in place. This was done to prevent any possible lifting of the rods and consequent cracking of the concrete due to changes of load.

The manufacturers of accessories have certainly exercised a tremendous amount of ingenuity in designing all kinds of expensive devices for attaching cables to anchorages. These consist of heavy forgings with eyes and offsets — in fact, nearly

everything that a man who pays the bills does not want — but nothing simple and practical seemed to be procurable in the market. We were, therefore, forced to design our own anchorage connections, which you will observe from the drawings are two $2\frac{1}{2}$-in. rods, threaded on the ends, which pass through the plate bearing on the two I-beams in the anchorages on one end and through the two holes in the block attached to the end of the cable on the other. This arrangement gives us an excess of strength over that of the cable and a very ready means of adjustment, and is about as simple to make as is possible.

Suspenders. — The suspenders, placed 20-ft. centers, are $\frac{3}{4}$-in. round iron, with an eye on one end threaded on the other, and supplied with a beveled cast-iron washer for bearing against the wooden structure. The clips for the attachments to the cables are made of $2\frac{1}{4}$-in. and $\frac{3}{16}$-in. band iron, punched and bent as shown by the dotted lines; after being placed on the cable, they were pulled together and the bolts and suspender attached. This form of clip gives a good grip on the cable without danger of injury to it and at the same time it allows free movement of the suspender rod. I might make the same remarks about these clips as about the anchorage attachments; the cheapest device we could find on the market for this class of work would cost from 8 cents to 10 cents per pound, whereas these clips and suspenders were purchased for $3\frac{5}{8}$ cents per pound, f. o. b. delivered at the bridge site.

Roadway. — In the design of the roadway, we endeavored to get a structure the material for which could be gotten out at the mill, thus doing away with much skilled labor at the bridge and at the same time have a structure which could be easily erected. It is quite apparent that the erection is one of the principal problems in a bridge of this nature.

The suspender rods are attached in pairs to a 4-in. by 6-in. timber 10 ft. long, the rods at the point of attachment being 6 ft. center to center. On this timber rest the main trusses which are 5 ft. deep, with a bottom member composed of one 3-in. by 6-in. and one 2-in. by 6-in., spaced 2 in. apart. The top member is composed of two 2 by 6's and a 2 by 8 as a cover strip. The diagonals are 2 by 6 placed between the double top and bottom members and thoroughly spiked in place. This structure gives the desired strength, the trusses being sufficient to carry the load on a 40-ft. span.

All the shaped pieces were made at the mill. The method of splicing was extremely simple and the erection pieces could be

handled without expensive tackle. The splicing was taken care of in the following manner: The double top and bottom members were staggered about 2 ft. When two sections were brought together, a 6-ft. piece of 2 by 6 was placed between the timbers of the truss and the whole bolted and spiked together. The trusses are kept in place on the supporting timber by a piece of 2 by 4 spiked to it, the floor boards holding the trusses from separating. Vertically they are held in place by two 2 by 4's spiked to the bearing timbers and the top members of the trusses.

Erection. — The plant used in the erection consisted of the usual amount of hand tools, a fair amount of blocks and tackle and a very small hoisting engine. Fortunately, to accomplish the desired results, we had a gang of erectors who would have been at home in some prehistoric age, as they were at least half monkey. This may be illustrated by the fact that not one of them was dropped overboard.

The framing and erection of the towers was straight ahead work, as was also the building of the anchorages. The next problem was to string the cables. They were received with end blocks attached, each on a reel weighing about 5 tons. The reels were first placed near their respective anchorages on the mainland side and blocked up to revolve freely. Next, a brake was rigged on each reel. We had strict orders — and a big section gang was on hand to see that they were obeyed — not to block the railroad tracks. To overcome any danger of this, an "A" frame was erected on the bank above the tracks, the block on the end of the cable was carried through a loop and the loop hoisted to the top of the "A" frame to a point about 25 ft. above the tracks. The $\frac{3}{4}$-in. cable, which was afterward to be used as the guy line, was made fast to the small engine on the island side and strung over the two towers and made fast to the cable; the engine was then started and enough pressure applied to the brake on the reel to keep the cable from sagging over the tracks. When the reel was nearly unwound, a tackle was attached to the cable to hold back. As the end came off the reel, it was placed over the anchorage rods and the tackle slacked off until the anchorage took the strain. This part of the cable erection progressed without trouble, with the exception of getting the blocks over the tops of the towers. As these blocks weighed something over 500 lb., it was somewhat awkward to get them properly over the tower saddles; this, however, caused no serious delays.

After the end of the cable was over the second tower and the cable began to raise from the bottom of the river, our little engine promptly died. The brake, however, was good and held what we had. We then took two 3-sheave blocks, provided with a $1\frac{1}{2}$-in. line and made that fast to the cable and a convenient tree and put a team of horses on the fall line. This rig was considerably more powerful than the engine and was good for all but the last 6 ft., when the horses gave up. We then made things fast and got a three and a two-sheave block and rigged them on the fall line of the first tackle, put our team on that and she came home very nicely.

With the cables strung, the cradling of them and placing of suspenders was simply a matter of climbing. The trusses were made up on shore in 20-ft. lengths; these lengths were carried out and dropped in place, by hand power, on the supporting timbers previously attached to the suspender rods. No splicing was done except temporary connections of the bottom chords until all material was in place, when the suspenders were adjusted and the splices made up. When we had perhaps 150 ft. of structure hanging over the water, there came up a heavy wind storm, blowing four or five loose pieces of plank into the river. Some enterprising newspaper man saw the chance for a story and his next edition had something like this in big black headlines:

"BIG ACCIDENT AT VESPER COUNTRY CLUB.
CLUB MEMBERS AND ENGINEERS FORM A DISCONSOLATE GROUP AT RUINS OF THE NEW SUSPENSION BRIDGE."

As several of our men were on the bridge at the time, and as the most serious mishap occurring to any of them was the loss of one cap which blew away, we think the newspaper account must have been cooked up.

It had always been customary when the ferry was running to charge club members five cents for passage to the island, with free passage back. To derive revenue from the bridge without the services of an attendant, a turn-stile was provided on the island end of the bridge which would allow free passage over the bridge in one direction, and it was fitted with a slot-machine device by which, on deposit of a nickel, the turnstile would allow a one-quarter revolution. At last accounts, this device was working very satisfactorily, supplying sufficient revenue to eventually pay for the bridge.

The cost of the structure, including the trestle approaches, to the Vesper Country Club was a little over \$6 000, or slightly in excess of \$11 per foot of span.

The bridge was designed and constructed by Westinghouse, Church, Kerr & Co., of New York, reporting to the Bridge Committee of the Vesper Country Club, Mr. A. T. Safford, chairman. Mr. J. R. Worcester, of Boston, reviewed the plans for the Vesper Country Club.

DISCUSSION.

Mr. Arthur T. Safford. — It may be interesting to those present to hear a few of the conditions leading up to the building of this bridge and its performance since it was turned over to the club by Westinghouse, Church, Kerr & Co.

Previous to the building of the bridge, the Vesper Country Club, with a membership of 400 resident members and about 150 non-resident members, had been doing a total business of about \$17 000 a year, and had maintained a ferry operated by hand across the river during the summer. The club house was kept open the year round, but the patronage during the three winter months of the year was so small that the net loss to the club during this time was about \$1 000. The regular way to get to the club by electric car on the Tyngsboro side was rarely used. The only sure way to get there was on the north side of the river, by driving five miles from Lowell or walking two miles from the end of the Varnum Avenue car line. Occasionally, the ice on the Merrimack was thick enough to permit passing over, or the winter open enough to allow the ferry to be operated, but it was usually neither one thing nor the other.

Three schemes were studied by a committee of the club to provide access to the island during the winter months: 1. An extension of the Varnum Avenue car line, on the north side of the river to a point on the state highway opposite the club. 2. A system of barges to run from Lowell to the club at stated intervals. 3. A bridge from the main highway and the Tyngsboro car line to the island.

The first two schemes proved impossible to work out on account of the high cost of maintenance. The third appeared to offer the only satisfactory solution of the problem, but it was expected that a proper bridge would cost in excess of \$12 000. The matter was dropped by the club until Mr. Thomas, who came to Lowell in connection with some large work for the Hamilton Manufacturing Company, made the suggestion that a proper suspension bridge could be built for less than one half of the cost

which had been anticipated. This fact and the interest displayed by a number of the members of the club in this project led to the appointment of a committee who had final plans made for the bridge and awarded the contract for building it to Westinghouse, Church, Kerr & Co. Their plans, with some very helpful suggestions by the consulting engineer, Mr. J. R. Worcester, were carried out during the summer of 1908 as Mr. Thomas has described to you. Previous to the actual construction, it was necessary for the club to get an Act of Congress under which the bridge could be built across navigable waters in two states, and permission from the Boston & Maine Railroad to cross their tracks with the cables from the towers to the anchorages.

In the report of the committee of the club recommending the construction of this bridge, it was stated that receipts from the ferry for the last five years previous to 1908, at five cents per toll per person crossing, were about $400 for the season, and the expenditures for labor, etc., a little more than this amount, so that the ferry had been run at a slight loss.

The receipts for the year ending March 31, 1909, which represented the first nine months of the operation of the bridge, showed a gross revenue of $679.11, or 13 580 persons paying toll, and a clear profit of $236, after paying interest, taxes and maintenance. The corresponding figures for the six months ending October 1, 1909, showed a gross revenue of $832.84, or 16 657 persons paying toll, with a clear profit of $585.71. The next six months will bring the figures up to about $1 200 gross revenue for the year, of which nearly $800 will be profit, and the membership has increased from 550 to 800 since the bridge was completed. The club has already written off nearly $1 500 from the total cost of the bridge and plans to retire a certain number of bonds every year. The club business has increased to over $25 000 per year and the interest in club life is maintained through the year.

The automatic turnstile placed at the island-end of the bridge to receive the tolls has given very little trouble, the only repairs necessary being an occasional cleaning and oiling of the more delicate parts. It is as nearly automatic, frost proof, fire proof and fool proof as possible, and great credit is due the inventor of this machine. It was believed by the majority of the club that an automatic turnstile could not be built to register the tolls and keep irresponsible people off the island, and that we should be obliged to station a man to collect the tolls, but the turnstile has worked with almost absolute precision, and no attendant has been necessary.

It was thought that not over fifty persons, or about the capacity of one electric car, would be on the bridge at one time, but this number has been exceeded a good many times without apparent injury to the bridge. The Harvard class of 1906 had a reunion of one hundred and sixty members at the Country Club last summer, and, in their anxiety to get to their train, were all on the bridge at one time; and during automobile week about four thousand persons crossed each day during the races.

The swaying of the bridge which is both a swinging motion from one side to the other and an up-and-down motion, even since the additional lateral guys have been attached, is very trying to some people, and it is very easy for boys or strangers to exaggerate this motion, but the members of the club by this time have got their sea legs and few complain at all of the motion. For my own information, I had the total lateral sway of the bridge measured by means of five horizontal board gages nailed to the top downstream rail, at equal distances from the banks of the river, whose zeros were in line with the bridge at rest. The sway upstream and downstream was measured by reading these five gages at different times when persons were crossing the bridge, with two transits set up on opposite sides of the river on the line through the zeros of these gages, and the change in elevation of the floor of the bridge by the same instruments set level. These gages showed a total motion or upstream and downstream movement from 0.50 to 1.20 ft. near the ends of the bridge and from 2.20 to 2.85 ft. in the middle, the variation either way being just about one half these figures; at the same time the rise of the bridge floor was 0.79 feet and the fall was 0.76 ft. from its normal elevation. This movement gives the bridge a sinuous motion which can best be appreciated by any one who waits for the crowd to go across, and remains behind to note the results.

The only accident to the bridge since its completion has been the letting go on the island shore of one of the upstream eye bolts holding the ½-in. diagonal bracing. This happened during the extreme cold of the first winter, after the bridge was completed. Since that time, the club has regularly readjusted the main and guy cables of the bridge at the beginning and end of the winter season, and also at times of the hottest weather. The greatest known difference in elevation in the floor of the bridge due to the expansion of the cables was about 1½ ft. during the extremely hot weather of last summer, at which time the bridge was still at the required height above the Merrimack River.

The following information was obtained by the committee

with reference to the behavior of two other suspension foot bridges, one at Whitneyville, Conn., and the other at Waterville, Me.

"Your letter of inquiry, addressed to the Country Club, Whitneyville, regarding suspension bridge, has been handed to me, and I beg to advise that the bridge in question across Lake Whitney at the New Haven Country Club is 270 ft. long between the centers of the towers and the truss is 6 ft. wide and 5 ft. high, and the excessive vibration is controlled by side guys. Such a truss is necessarily flexible, and it is very easy for two or three mischievous boys to throw it into a state of vibration, which makes it very uncomfortable to walk over. The side guys are exceedingly useful in preventing this sort of thing from being carried too far. The cost of the steel work for our bridge was $2 838, the masonry work, foundations and anchorages $400.

With reference to the Waterville bridge:

"This suspension bridge is 400 ft. long by about 5 ft. wide and cost them $13 000 delivered here." . . . There is quite a vibration to the bridge when there is a heavy wind, and also when there is quite a crowd going across, and makes one feel something like going upstairs, when there are quite a number hurrying across.

Mr. Robert A. Marshall.* — There is very little I can add to Mr. Thomas's paper on the construction of the bridge, or to Mr. Safford's observations on "The Bridge in Action." There are one or two points of difference between this bridge and most of the light suspension bridges, which might be of interest.

It seems to be the practice of firms that manufacture cables and light suspension bridges to secure the desired stiffness by closely spacing the hangers by which the flooring is suspended, and using heavy timber stringers below and above the floor planking. This spacing has usually been less than 10 ft.

In this case we have a bridge of much greater length than usual for such light structures. The length between towers is 550 ft., and the trusses are only 5 ft. apart, center to center.

This length made it possible to get considerable unequal loading and deflection on the bridge; in its design we departed from the usual practice for light structures and introduced stiffening trusses to largely take care of the deflection from unequal loading.

The trusses were designed on the same lines that would be

* Member American Society of Civil Engineers.

used for the steel trusses of a suspension bridge, with heavy traffic loads to carry and distribute.

The hangers were spaced 20 ft. apart, and the trusses were designed for a combination of the following loadings:

(1) The bottom chord of truss supported the flooring between panel points of the truss.

(2) The live and dead load on a span of 20 ft. between hangers.

(3) The stresses as a stiffening truss to properly distribute unequal loads on the span.

The trusses were made of wood, and so placed that they acted as high hand rails.

After the design was worked out, it was found that it involved the use of no more timber than would have been necessary in the ordinary type of construction. There was also a considerable saving in the cost of the hangers.

The truss sections were made on shore in 20-ft. lengths and then assembled in place; they were then fastened together by the bottom chord splices. After the erection or assembling of the bridge had been completed, and all of the dead load placed on the cables, it was adjusted to its correct height and the top chords of the trusses spliced, thus bringing the stiffening truss into action at what might be called its working condition.

In the design of the trusses a good deal of attention was paid to laying them out so as to get joints of sufficient strength to take care of the shear and moments in the trusses. These were worked out in the office and carried out into the field with the addition of bolts to some of the specified nailed joints.

The rise and fall of the span, due to expansion and contraction of the cable, and also to the stretch of the cable under live load, made it necessary to allow for a longitudinal motion at the ends of the trusses. The ends were held both vertically and in sidewise position, but allowed to work lengthwise, so that when the cables rise in cold weather or under light load the ends of the trusses can draw together, and as the bridge sags in the center under heavy load or from cable expansion, the ends of the trusses will move back.

The design of the cables proved very interesting because economy of construction required us to figure the exact length of cables in the office and have the end blocks put on in the shop. Different conditions required several calculations for length. The first condition on erection would be the catenaries, formed between towers and between towers and anchorages. As the

dead load of the span was added, the latter catenaries decreased and there would be a certain stretch under the added load.

In order that expansion of the cables and stretch from live load would not lower the bridge below the established clearance, a height was established for adjustment at a temperature of 70 degrees, and a height variation given the superintendent so that he could adjust at any other temperature.

Mr. Thomas has already told you that, when adjusted, the block at one end was in correct position and about 6 in. out at the other, showing that our figured lengths were about 1-20 of 1 per cent. out. You have, doubtless, noticed from the pictures that we took precaution to have enough thread on the ends of the anchor rods to take care of a much greater error in length.

President George B. Francis. — As a part of the discussion has partaken of an historical nature, it may prove interesting to recite a few more facts of history regarding American bridges.

These facts may be well known to some and not to others. They are taken from the presidential address of Mr. C. C. Schneider, delivered before the American Society of Civil Engineers in 1905.

"The first wrought-iron link suspension bridge in this country was built by Finly, in 1796, on Jacobs Creek, Fayette County, Pa." "The first wire cable suspension bridge was built over the Schuylkill River at Philadelphia, in 1816."

"Up to 1840 there were no iron bridges in this country, except suspension bridges, in which iron links were used in the cables and suspenders, the floor system being of wood."

"The first bridge in America consisting of iron throughout was built in 1840 by Earl Trumbull over the Erie Canal in the village of Frankfort, N. Y." "In the same year Squire Whipple also built his first iron truss bridge."

"Probably the first iron railroad bridge was built on the Philadelphia & Reading Railroad at Manayunk, in 1845."

"The Howe truss was patented in 1840."

The period from 1850 to 1860 brought into use the Fink, Bollman, Whipple and Pratt designs.

"All the earlier bridges were built principally of cast iron, wrought iron being used in tension members only."

"The first bridges made entirely of wrought iron were those of the riveted lattice type," and date from 1859.

"The plate girder type came into use on the Boston & Albany Railroad, in 1860."

"The first pin-connected bridge constructed entirely of wrought iron, excepting for joint boxes connecting the compromise members, which were of cast iron, was built in 1863."

"Up to 1872 specifications, as we now understand the term, were not in general use."

"Steel, as a structural material, was first used in a portion of the St. Louis bridge, completed in 1874."

"The first bridge built entirely of steel was the Glasgow bridge over the Missouri River, completed in 1879."

"The extensive use of steel, however, did not commence until 1890."

"In 1894 it was practically impossible to obtain wrought-iron shapes. The year 1894, therefore, may be considered as the commencement of the present epoch — the steel age."

The first nickel steel used in bridges was used in the Queensboro bridge at New York about 1898, where it was used for eye bars only.

Plans approved this year, 1909, for the new bridge over the Mississippi River at St. Louis require nickel steel throughout the trusses at equivalent ultimate cost to rolled steel. The saving in weight of metal offsetting the greater cost per pound of nickel steel.

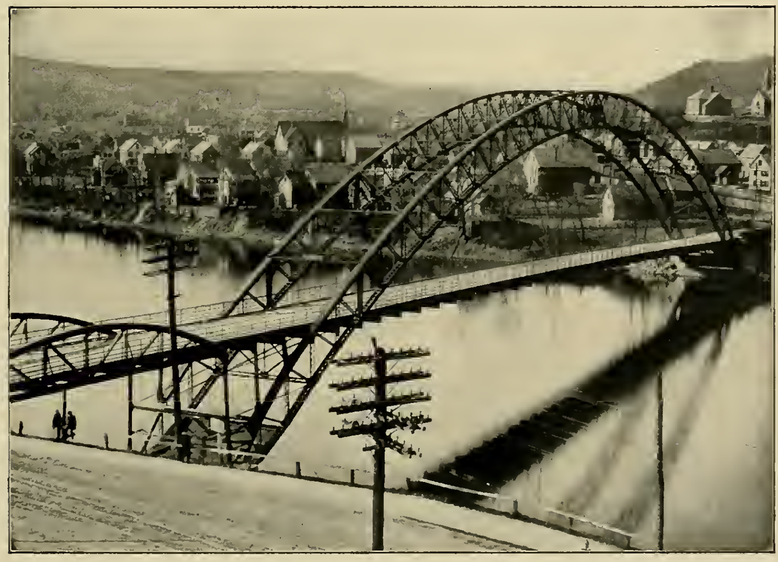
"Metal arch bridges have been constructed of cast iron, wrought iron and steel. The first one in this country was built in 1863."

"The first cantilever railroad bridge in this country was built in 1877 over the Kentucky River on the Cincinnati & Southern Railway."

Mr. Schneider says, "It is entirely feasible to build simple trusses of 800-ft. arches and cantilevers of 2 000 ft. and wire cable suspension bridges of 3 000 ft. span."

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 1, 1910, for publication in a subsequent number of the JOURNAL.]

End View, Bellows Falls Arch Bridge.



The Bellows Falls Arch Bridge.

(Reproduced by courtesy of the American Society of Civil Engineers.)

BELLOWS FALLS ARCH BRIDGE.

By Joseph R. Worcester, Member Boston Society of Civil Engineers.

[Read before the Society, December 15, 1909.]

The Bellows Falls Bridge was constructed to meet a long-felt and constantly increasing need of connecting the towns of Walpole, N. H., and Rockingham, Vt. The west shore of the Connecticut River at this point marks the dividing line between the states of New Hampshire and Vermont, as well as between the towns, and the fact of the divided ownership added to the difficulty of initiating action. Up to this time the only means of crossing had been by the Toll Bridge, owned by the Canal Company, located some distance out of the direct line of travel, and the Boston & Maine Railroad Bridge, running in a more direct line between the mills in Bellows Falls and the fast-growing residence section of North Walpole. This use of the railroad bridge was dangerous and very objectionable from the standpoint of the railroad. The importance of easy communication between the two places was felt not only by the mill operatives who resided in North Walpole, but also by those living in a "dry" town who sometimes had occasion to visit one where licenses were granted.

The earliest steps for the construction of the bridge which came to the notice of the writer were in the fall of 1903, about a year before the bridge was actually started. At that time a Citizens' Committee was appointed by North Walpole residents, to see what could be done with regard to building a bridge and to procuring estimates of the cost. The appointment of this committee becoming known to bridge builders, a great deal of gratuitous advice was tendered, and the committee found itself somewhat embarrassed by the number and variety of the schemes suggested. One of the difficulties anticipated was opposition by the Canal Company, which owned the Toll Bridge and also the water rights as well as land along the shores of the river. The committee thought that in order to avoid complications with the Canal Company, it would be necessary to avoid wholly the use of piers within the river, and this involved either a span of over 500 ft. or the use of two spans making a considerable angle with

each other, so as to take advantage of the support of the central pier on an outcropping of ledge at about the center of the dam.

At about this stage of the investigation the writer was consulted to assist the committee in deciding which location and design to adopt, and to help with an estimate of the cost. He was assured by the committee that while it had no funds to pay for engineering advice, it would use its efforts to secure him the position of consulting engineer in case the towns accepted their report.

After considering all the plans proposed, and the preferences of the committee, a rough plan was drawn up and an estimate prepared on the basis of the two-span location, which, though admittedly objectionable, seemed to be most feasible on account of the expense.

The next work undertaken by the committee was to induce the towns to appropriate the necessary amount of money for the construction of the bridge, and this matter was brought before town meetings on both sides of the river. In the meantime, the towns were advised by the officials of the Canal Company that they would not offer any opposition to the construction of the bridge provided the towns would appropriate sufficient money, about $20 000, to free the Toll Bridge, and the advisers of the towns considered that this would be the best policy. In accordance with this idea, a sufficient amount of money for both bridges was eventually appropriated by the two towns: one third by Rockingham, and two thirds by Walpole. This singular division of the cost was on account of the location of the state line at the low-water mark on the Vermont side, making the larger portion of the bridge in the state of New Hampshire.

While the town meetings acted practically along the lines suggested by this Walpole committee, they proceeded to completely turn the members down by placing the construction of the bridge in the hands of a joint commission of entirely different persons. This naturally eliminated the writer from the problem for the time being, and the efforts of the committee in his behalf came to naught.

The new commission at the outset of its deliberations rejected the idea of a two-span bridge, largely because the members thought the location of the central pier was so near the railroad that horses would be frightened. With the two-span design out of the question, and the belief that no piers could be placed in the river at all, it naturally looked doubtful whether the money appropriated would be sufficient to pay for any kind of bridge. The commission had spent several months in entertaining bridge

agents and discussing the question, without accomplishing anything, when the president of the Boston & Maine Railroad came to its relief with an offer of the services and advice of his engineering department, which was gratefully accepted. Mr. Snow, not having time to prepare plans, called for competitive bids and designs, based upon a specification which prescribed very little with regard to the bridge, except as to its capacity and dimensions, and that it should have a span of approximately 540 ft., without piers in the river.

The bidders who submitted plans upon this invitation chose for a design either a suspension or a truss type, and either did not think of an arch or thought it impracticable. As a matter of fact, however, the profile was not favorable for a suspension bridge on account of the lack of space for anchor arms, and the same feature prevented cantilever construction. A plain truss for a light load was extremely attenuated and awkward. It was not surprising that all the proposals were above the appropriation and the designs unsatisfactory to Mr. Snow. Learning of these conditions, and having made a preliminary estimate upon an arch, the writer had a conference with Mr. Snow which resulted in his advising the commission to reject all bids and to engage an engineer to make plans upon which new figures could be obtained. The design upon which this suggestion to Mr. Snow was based included an arch with a suspended floor, very much as it was finally built, and though the estimates had been made in one evening in a very superficial manner, they fell so far within the required amount that they seemed to warrant quite positive assertions as to the outside cost.

The line of thought which led to the development of the design began with the idea of a reinforced concrete arch, but it was soon found that this was altogether impracticable with any view of economy. A steel arch was considered, having a roadway over the top, but as the height of the roadway above the water was quite limited, this scheme also was soon ruled out. It led, however, naturally enough, to the conclusion that if the arch could be made to spring from a low level and could be carried up to an economical height, there would be no difficulty in running the roadway through on a uniform grade, part being above the arch and part below, suspended by vertical posts and hangers. At the time I had no definite recollection of any bridge of this character, although there was a lingering thought in my mind that it was not at all novel. This was afterwards confirmed by my learning of two bridges of similar design across the Rhine,

which had been illustrated some time previously in one of the American engineering periodicals.

Mr. Snow's recommendation to the commission was accepted and resulted in an arrangement for the making of detailed drawings and specifications to be paid for by the towns provided satisfactory bids were received allowing for the payment of the engineer within the appropriation. This risk proved to be slight, for satisfactory bids were received from a number of bridge builders. The contracts were awarded to Lewis F. Shoemaker & Co. for the superstructure and Joseph Ross & Sons for the substructure. The cost of the superstructure was $41 000, and of the substructure, $6 000, or a total of about $70 per linear foot.

The following is a brief description of the principal span, there being besides this a short span over the Rutland Railroad.

The arches are three-hinged, riveted trusses, having a span between end pins of 540 ft. and a rise of 90 ft. The end bearings are on pins, and the center a simple contact bearing of plates at the mid depth of the truss. The trusses are 30 ft. on centers, with a roadway 20 ft. wide, and a 6-ft. sidewalk. The roadway floor is a single thickness of plank on steel stringers. The roadway is on a grade so that the ends are not symmetrical, though the paneling is kept so. The floor has a lateral system independent of that of the trusses, except that it bears against the latter where it passes through. The suspenders are square rods with pin connections top and bottom.

The loads provided for were 60 lb. per sq. ft. for the arches, with a provision of 100 lb. per sq. ft. for the floor system and hangers, or a concentration of 12 tons on 4 wheels. Wind force to the extent of 40 lb. per sq. ft. was provided for in the lateral systems. These loads have proved sufficient so far even for the purpose of carrying elephants.

A mistake was made in locating the spring of the arch so low that when the ice goes out in the spring it sometimes strikes the steel work with great force, and on one occasion broke a lateral connection. This has now been guarded against by constructing a wooden shield along the two lower panels of the bottom chord. The expense would have been much greater had the pins been higher.

The contracts were let in the early summer, and work on the foundations began soon after. In excavating for the piers and abutments it was found that the soil underneath the alluvial silt was a fairly clean, sharp gravel and sand. The contract had provided for piles under the foundations upon the expectation

that the material would be softer than it had turned out to be. It was something of a question whether it would not have been safe to omit the piles, but considering the possibility of undermining through scour, Mr. Snow decided to use the piles, notwithstanding the hard driving. It was expected that there would be no difficulty in getting the steelwork early in the fall so that it could be erected before winter, but on account of various delays in the shop, it was not until November that the steel arrived on the ground and erection could commence. This lateness of the season for erecting was somewhat hazardous, for the reason that occasionally the river rises and the ice goes out during the month of December. Such an event would have undoubtedly carried away the falsework with everything supported by it, and might have entailed a very severe loss. Nevertheless, the contractor ran the risk and it turned out that the weather was, on the whole, favorable, although extremely cold.

The method of erection has been thoroughly described by Mr. Lewis D. Rights in a paper before the American Society of Civil Engineers.* Mr. Rights is to be credited with the ingenious method of erection by cantilevering over the occasional towers, and with the care exercised in making preparations for every emergency during the progress of the work. It was a great relief to everybody when, on January 10, 1905, the last plates were inserted between the central ends of the arch ribs and the wedges were knocked out, allowing the steel to carry itself. Then it was felt it would not matter seriously if the river should rise, but it did not, and no trouble was found in taking down the falsework and clearing up the site. The time required for the erection of the arches was only twenty-eight working days.

The details of the design of the bridge were worked out by Mr. E. E. Pettee, who should be credited with many of the best features of the design. The triangulation for the location was performed with success by Mr. G. H. Brazer. The supervision of the work was under Mr. J. P. Snow from the start, who was represented on the ground by his inspector, Mr. C. H. Restall. The writer was not represented directly in connection with the erection, but was kept informed as to the progress of the work by Mr. G. V. White, who had made all the preliminary surveys and who kept a record of the erection by means of an excellent series of progress photographs.

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* Transactions American Society of Civil Engineers, Vol. LXI, p. 253.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 1, 1910, for publication in a subsequent number of the Journal.]

WATERPROOFING OF ENGINEERING STRUCTURES.

By Joseph H. O'Brien, Member Boston Society of Civil Engineers.

[Read before the Society, November 17, 1909.]

The purpose of this paper is neither to record the history and development of the art of waterproofing nor to discuss the merits of the various methods employed, but simply to present some points of possible general interest, and to briefly describe waterproofing by use of pitch and felt, of certain viaducts, retaining walls, cut and cover tunnels, pipe subways, elevator pits, conduit banks, etc., which have been designed and constructed in New York City under the writer's supervision. The work to be described was performed under three separate contracts, but the materials used were the same in each case, the specifications varying only as to number of plies, methods of procedure and character of backing, or protection of waterproofed surface.

The clauses of the specifications, which apply to materials and application, are as follows:

"Pitch used shall be straight run coal-tar pitch, which shall soften at 60 degrees fahr. and melt at 100 degrees fahr., being a grade in which distillate oils distilled therefrom shall have a specific gravity of 1.105."

"The felt shall be 'Hydrex' felt, manufactured by F. W. Bird & Son, East Walpole, Mass.,* or felt equally satisfactory to the engineers."

"Pitch, when applied, shall be of a temperature of not less than 250 degrees fahr. The pitch shall be mopped on the surface of the masonry to a uniform thickness of not less than 1-16 in. Each layer of pitch must completely cover the surface on which it is spread without cracks or blow holes. The felt must be rolled out into the pitch while the latter is still hot and pressed against it so as to insure its being completely stuck to the pitch over its entire surface. Great care must be taken that all joints in the felt are well broken, and that the ends of the rolls of the bottom layer are carried up on the inside of the layers on the sides, and those of the roof down on the outside of the layers on the sides, so as to secure the full laps herein specified."

Other important clauses are:

"It is intended that the interior of waterproof structures shall be permanently free from moisture or discoloration due to

* Now the Hydrex Felt and Engineering Company.

the percolation of water or other liquids from outside sources. This end shall be attained by means of a continuous flexible waterproof sheet surrounding the exterior of the structures (as shown by drawings)."

"Waterproofing must be protected against injury at all times to the satisfaction of the engineers."

"Any waterproofed structure that is found to leak at any time prior to the completion of this contract, shall be made tight by the contractor in a manner satisfactory to the engineers."

"Waterproofing will be measured by the square of 100 superficial feet and paid for accordingly."

Composition of the waterproof sheet is specified as follows:

"For all construction, except electric conduit lines and electric conduit manholes, waterproofing shall consist of six layers of felt and seven layers of pitch alternating, and shall consist of four layers of felt and five layers of pitch alternating, for electric conduit lines and manholes, each strip to lap not less than 1 ft. upon the previously laid strip, and each section of waterproof sheet shall lap at least 1 ft. with the adjoining section."

The specifications have, in most particulars, served their purpose admirably, but the following comments may be of interest:

The felt used comes in rolls 36 in. wide, and each roll contains 400 sq. ft. The method of practical procedure to be followed in placing the felt so that the specification requirements as to laps might be complied with, caused much concern.

In the writer's judgment, the most effective way to lap the plies is by the "shingle method," or, as sometimes called, the "feather-edge method," similar in principle to that employed in pitch and felt roofing; but it is evident that with felt sheets only 36 in. wide, the prescribed lap of 12 in. cannot be effected in six-ply work by the "shingle method," and because of the superiority of this method, it was concluded to fit the laps to the felt, and the work was actually carried out wherever practicable with 6-in. laps "feather-edged" or "shingled." The felt was laid transversely of the structures. The requirement "each strip to lap not less than 1 ft. upon the previously laid strip" occasioned some confusion, owing to the fact that it might be interpreted to mean that each 36 in. strip should lap the prescribed amount at edges and ends over the previously laid strip of the ply of which it was a part, but as this was manifestly impracticable, the requirement was interpreted as applying to the relation of the joints in one ply to the joints in the ply beneath it, as was doubtless intended; but, as stated above, the lap was reduced to 6 in.

The usual waterproofing practice of sticking each strip to

its neighbor by lapping at least 1 in. was followed in making up each ply. The writer believes that a better result will be obtained, however, if this butt lap (so called) be made 2 in. wide.

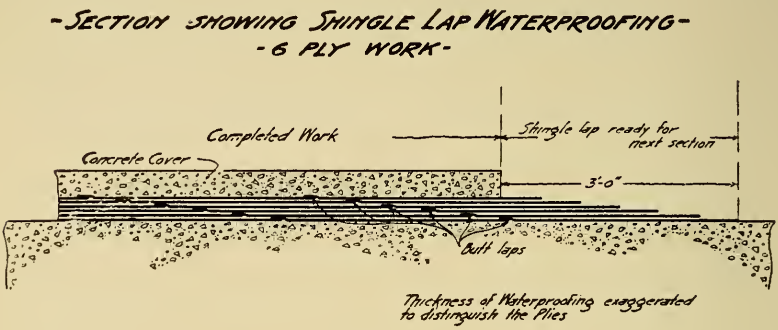


FIG. 1.

The system of shingling adopted keeps the shingle at the head of the work with all six plies in evidence, and with all sheets securely stuck, as shown in Fig. 1. Thus the waterproof sheet is entirely completed back of the shingle lap, and may be covered and permanently protected up to the lap. By this method there is little difficulty in obtaining the correct number of plies, and, in the writer's opinion, the method gives the best obtainable quality of work.

In providing for connection of two sections of standing work, as in subways, or for connection of standing work and flat work, as at tops of walls, dry laps were left, which appeared at first to be the only solution of the problem which would insure a continuous waterproof sheet of the character intended; but on six-ply work this procedure required that dry ends of sheets varying from 6 in. to 36 in. be left, in order to effect the shingle bond with the flat or standing work, as the case might be. (See Fig. 2.) Despite the specification requirements that "waterproofing must be protected from injury at all times to the satisfaction of the engineers," the writer does not hesitate to state that it was quite impracticable to protect dry laps, and despite all efforts made to do so, such laps were invariably found almost wholly destroyed and unfit to join on to, when ready to proceed with the connecting waterproofing.

The destruction of dry laps was due to various causes, such as dragging timber and other materials over them, deposits of débris and of concrete from the work preceding the next waterproofing stage, traffic of laborers over them, and last, but by no

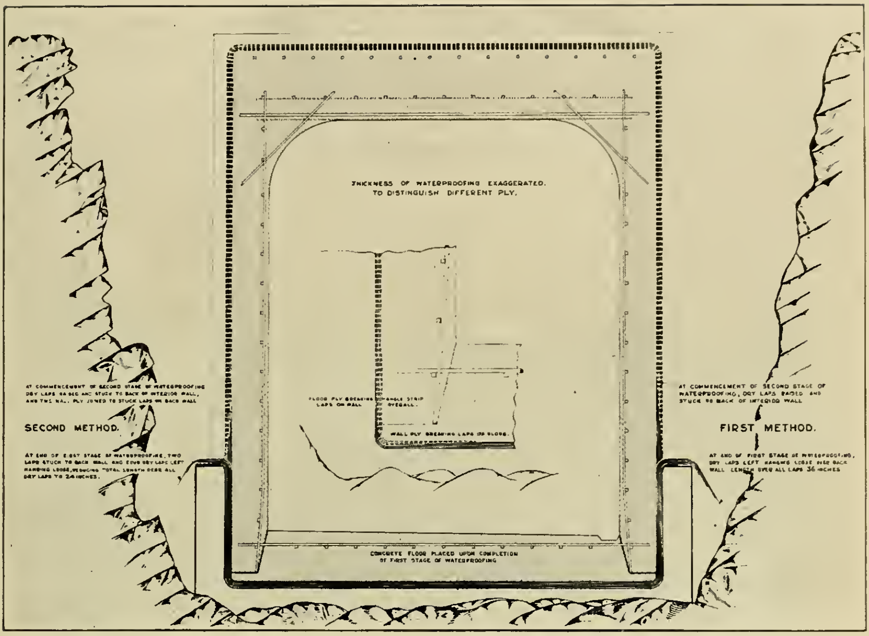


FIG. 2 AND (IN MIDDLE) FIG. 2-A.

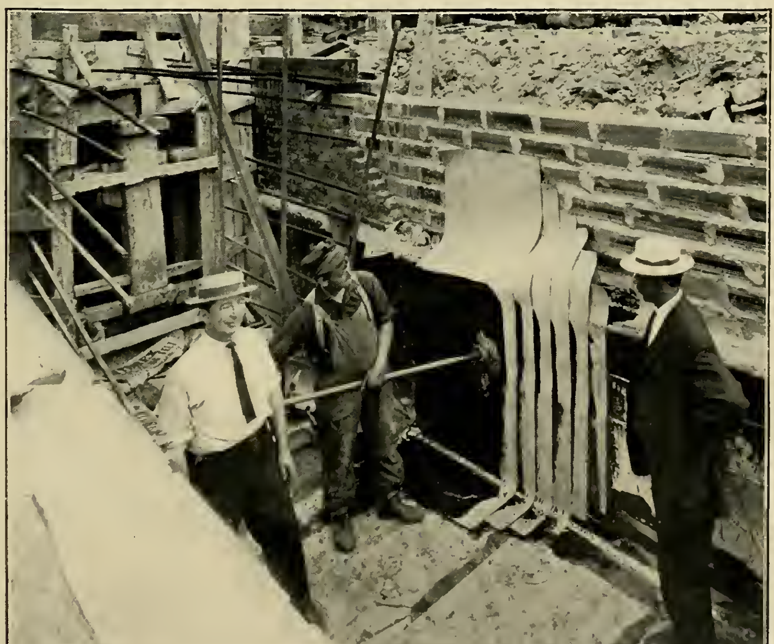
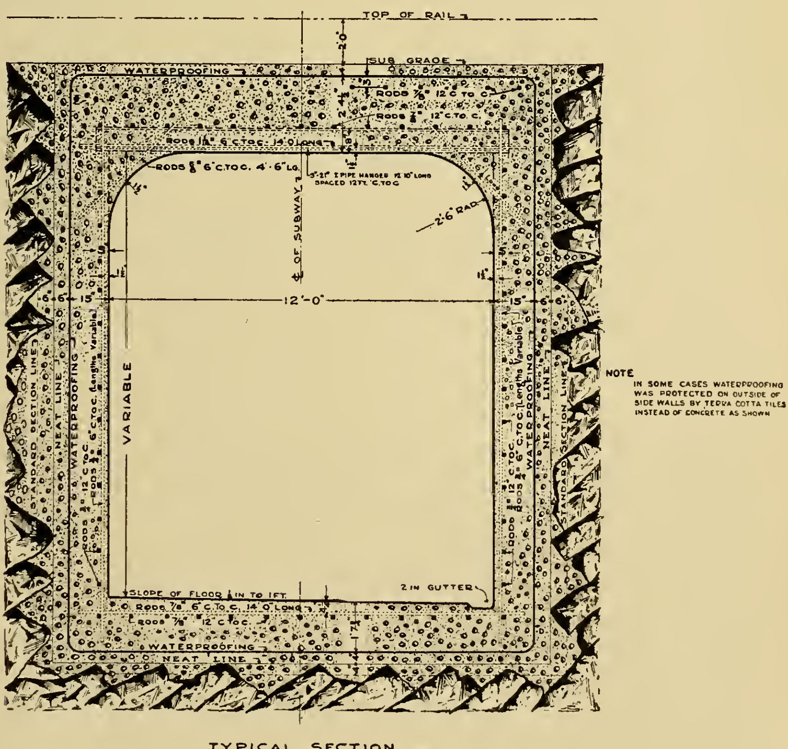


FIG. 4-A.

FIG. 4.

means least, the absorption of water. If the felt becomes water-soaked, it is thereby destroyed. The saturation and coating of high-grade felts, such as that used on the work described herein, renders the sheets impervious to water on their surfaces, but the edges are not impervious, hence the necessity for so conducting the work that the edges of the felt be at all times protected from the influence of water.

To overcome the trouble experienced with dry laps, the total lap was reduced from 36 in. to 24 in. for connections of standing work, sticking the two first sheets solid on the top of the backing wall, leaving four dry laps of 6 in., 12 in., 18 in., and 24 in. for the remaining plies. (See Fig. 2.) Then when the joining was effected, four plies were carried through by shingle method, and two plies were stuck by solid lap method. Due to the reduction in width of total dry lap, the felt was more easily preserved, but the destruction of these laps was not wholly avoided.



TYPICAL SECTION
OF 12 FT. TRUCKING AND PIPE SUBWAY

FIG. 3.

The writer believes that, under similar conditions, the best procedure would be to reduce the dry laps to two plies and stick four plies with solid lap. This solution of the difficulty is wholly a practical suggestion, which does not satisfy theoretical consideration of the problem, but will none the less give good results.

The instances of dry laps so far discussed and illustrated were an incident of the construction of the reinforced concrete subways, for pipes, wires and express trucking, about a mile of which, varying in clear width from 6 ft. to 17 ft., have been constructed beneath track grade. The procedure which brought about the above-noted conditions may be more readily understood if we depart a little from the subject and briefly describe and illustrate a typical subway. The cross-section (Fig. 3) shows a subway 12 ft. wide, and varying from 12 ft. to 17 ft. high inside, designed to carry a railroad on its roof, and to resist hydrostatic pressure, due to an assumed head, measured from the average level of the open joint drainage system, which is about 1 ft. 6 in. below the roof of the subway. It will be noted that the excavation is wholly in rock, and the drawing requires that a volume be excavated only 6 in. wider on each side than the neat section. The nature of the rock was such, however, that the trench was blown out from 5 ft. to 10 ft. wider than required in places.

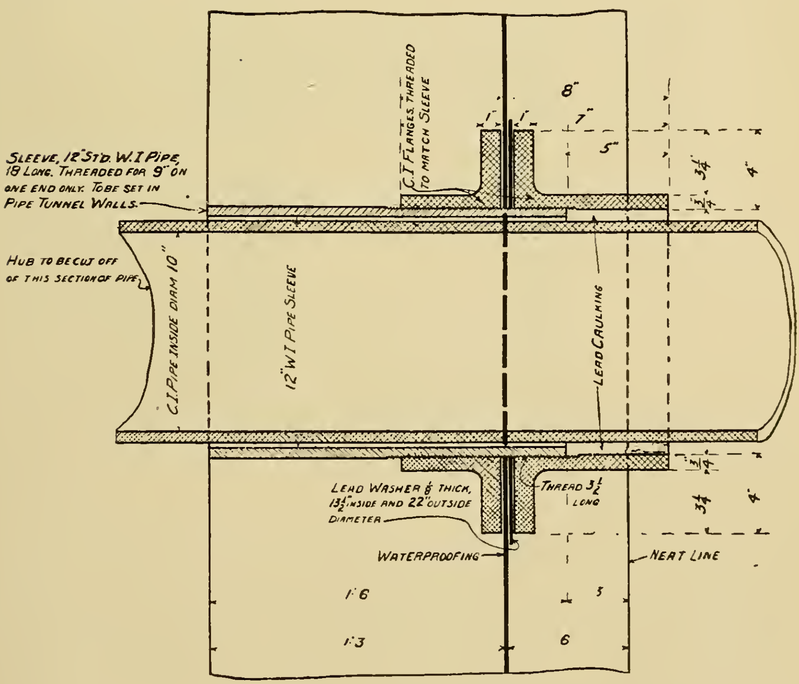
The first step after completing the excavation was to build the floor base and backing walls ready for waterproofing.

After careful consideration, it was determined to make the backing walls 12 in. thick, and to limit their height to 4 ft. in the first stage. (See Fig. 2.) The height determined upon was sufficient to keep water out of the waterproofed trench, except occasional flooding after heavy rains, and it was a convenient bench from which to work in placing rod reinforcement against interior forms, and upon which to construct exterior forms of the subway. It was considered, owing to lapse of time which must ensue in constructing the monolithic tube within the waterproof enclosure, that standing work would probably often be lost if carried higher than 4 ft., by sags due to weight of fabric and augmented by temperature exposure. Likewise the danger of damaging the fabric while building the reinforced tube inside of it was anticipated. Fears in respect to these matters were fully justified, as illustrated, by the case of an 8-ft. subway, which was so situated that the complete waterproof sheet had to be placed up to the roof connection, and the subway built

within. Much valuable waterproofing work was destroyed in this trench, due to the causes above cited.

Another point bearing upon the practical application of the felt in the first stage of the subway waterproofing, above referred to, and in similar situations, is the importance of so making angles and corners that they will be durable during construction and tight after. Angles at junction of flat and standing work are natural weak spots in pitch and felt waterproofing.

In the subways referred to, the first scheme tried required that the sheets be carried full across the floor and up both backing walls in one continuous strip, but two very serious objections to this procedure soon became evident. In the first place it was impracticable to securely stick the sheets throughout, especially at the angles of floor and walls, and as a result, the standing work bulged and sagged. In the second place, the scheme resulted in much waste of material, and annoyance to the contractor, who was accustomed to cut and fit according to his material, with a minimum of waste.



SLEEVE FOR 10 IN. C.I. PIPE.

FIG. 5.

The method was changed, therefore, so that the floor plies would break joint with the wall plies, partly on the wall, and partly on the floor, as shown in Fig. 2-A, and as an additional safeguard a strip was laid longitudinally and fitted snug into the angle over all, and this was found to be a very practical and satisfactory solution of the detail.

Fig. 4 shows the waterproofing of floor and backing walls, proceeding according to the method last described. Fig. 4-A clearly shows the method of waterproofing backing walls of subways. It was found necessary to leave openings in the walls of pipe subways for pipes varying in diameter from 1½ in. to 12 in., and in order to insure a watertight job upon completion, screw sleeves with sheet lead washers, and with calking rims were devised, as shown in Fig. 5. The pipe sleeve details were designed to permit of the introduction of the pipes after the subways had been completed. The sleeves were easily applied and the use of them has so far resulted in tight work.

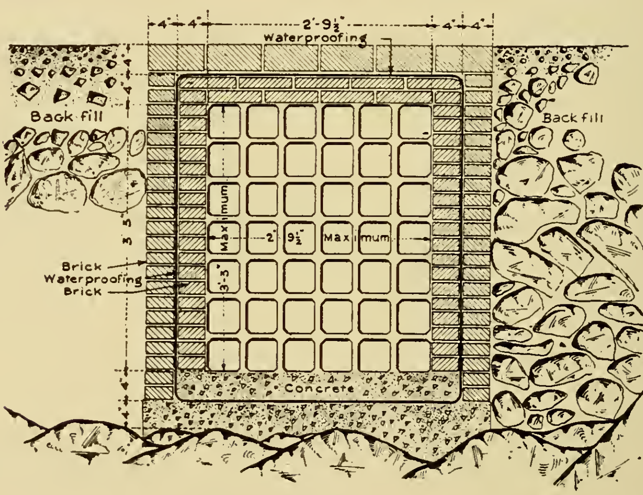


Fig. 6.

In conduit bank waterproofing, several miles of which were included in the work herein described, dry laps were left at first on the flat at the floor base, owing to the necessity for laying the conduits in advance of placing the side wall and roof waterproofing. Fig. 6 shows section of typical conduit bank, and Fig. 7 shows first stage of waterproofing with dry laps.

Practically all of the laps beyond the edge of the masonry base were found to be destroyed when the conduits had been

made ready for completion of the waterproofing, hence the laps were reduced successively to two dry and two stuck, and finally to all four stuck of the width of base projection beyond the conduits. Wherever conditions made it possible to require the construction of the complete waterproof basin to the top of the conduits in advance of laying the latter, this practice was followed, but while it produced the best job of waterproofing, it required the construction of the conduit bank end on in a narrow

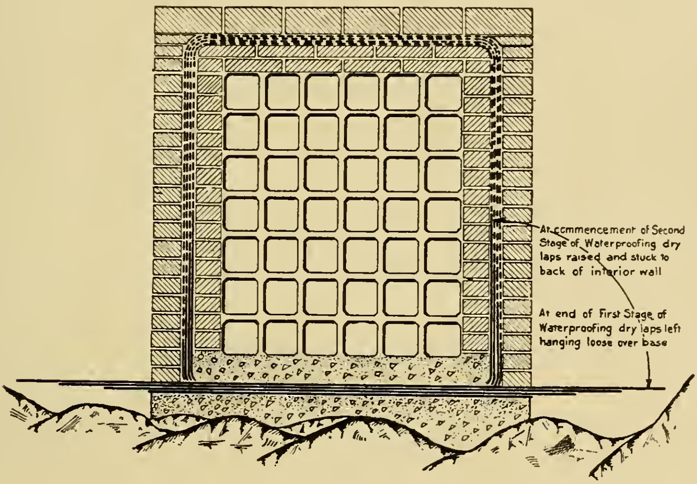


FIG. 7.
Thickness of waterproofing exaggerated to distinguish different ply.

trench, at the risk of bad duct alignment. Furthermore, the rate of progress by this latter method was very much less than by the method generally followed.

In the writer's judgment, however, and despite the fact that tight work has been obtained by the method of first placing the floor sheets, joining the wall and roof sheets to them, after the duct bank was made ready, it would be better, where similar work is required, henceforth to design the waterproofed trench of sufficient width, and with suitable backing walls to permit of the construction of the ducts in the usual manner, after the trench has been completely waterproofed.

Waterproofing of baggage lift pits was placed in accordance with the principles outlined above for pipe subways, but the pits were open at the top and one end, and the waterproofing problem was complicated by the presence of foundations for superstructure columns, and by the necessity of providing for plungers.

It was determined that the plunger borings should be made after the baggage lift pits were completed, and to insure a water-tight pit, a plunger casting was devised, with a clamping ring and stud ring, between which the waterproofing was placed (see Fig. 8).

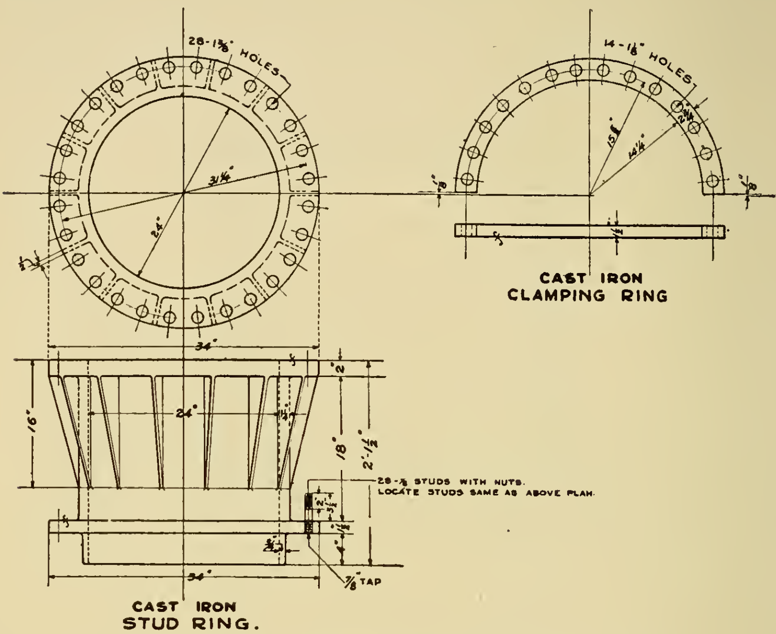


Fig. 8. Detail of Castings for Waterproofing Hydraulic Elevator Pits at Plunger Cylinder.

This casting had to be set accurately and securely in position, hence the base course of concrete was carried through beneath it, and the casting was set on same, and stayed by lateral bracing during the placing of the finished work. The detail of the casting required that the connecting sheets of waterproofing be cut to fit the stud bolts, which was a rather unusual waterproofing detail, but a very satisfactory result was obtained.

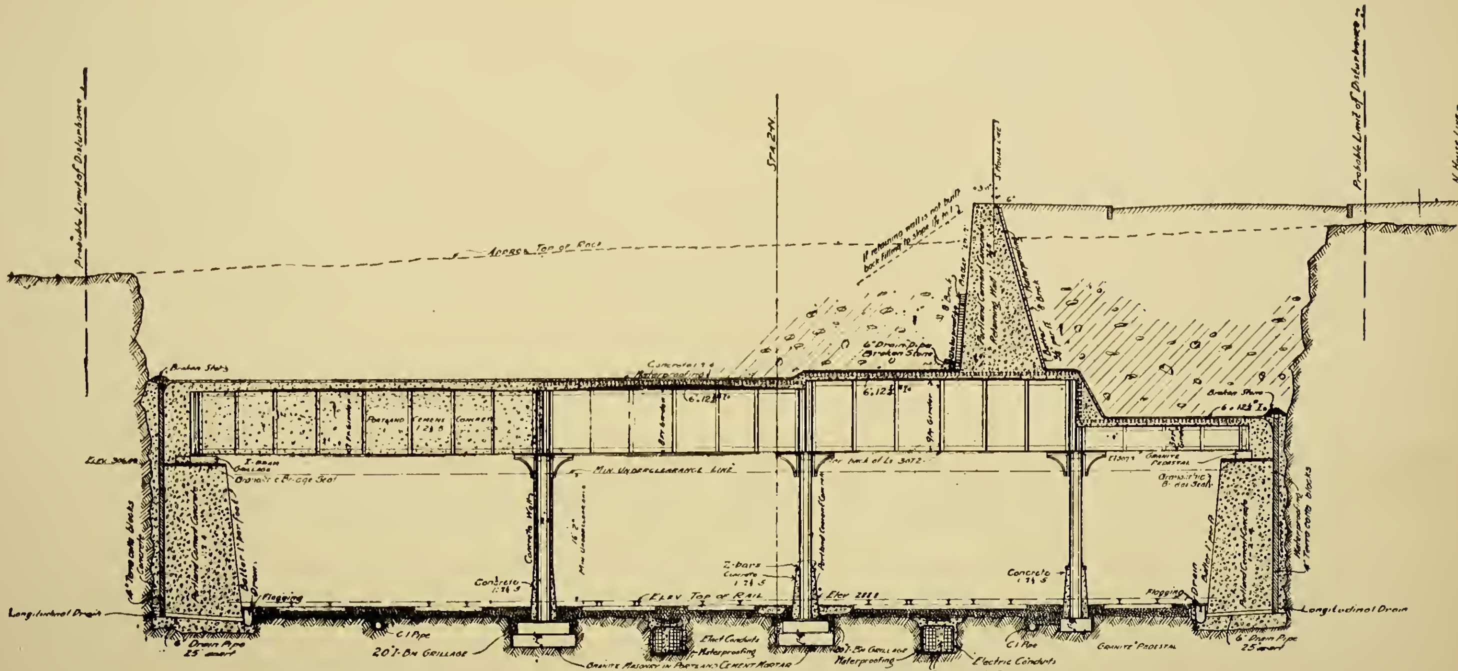
Due to a necessity which arose, bearing upon the general advancement of the project, the backing walls of two baggage lift pits, which had been excavated for most of their height through earth, were placed in the form of retaining walls some months in advance of the completion of the lift pits, and construction tracks were carried over them on temporary trestle stringers.

After the floors of these pits were completed, the steel

framing of the walls (composed of 15 in. I-beam studs, set apart 4 ft. 0 in. centers) was erected, in advance of completing the waterproofing, because it was feared that the waterproofing, if completed first, would be destroyed during erection of the steel. The procedure followed made the placing of the waterproofing a very difficult job. To overcome the difficulty, mats were prepared to fit the spaces back of the beams. These mats were made up of sheets varying in width from about 12 in. for the sheet next to the beam flange to 36 in. for the sheet next to the backing wall. The mats were made up and mopped complete on the adjoining subway roof, and were lowered into place and securely stuck. After any two mats of a panel had been placed, the intervening space was waterproofed in the usual manner. The joining between floor and wall work was effected by solid lap method, and the joint was protected by three courses of brickwork in Portland cement mortar, set about 3 in. away from the wall waterproofing, thus forming a pocket which was filled with pitch.

In the case of one viaduct which was constructed under an avenue, the waterproofing was placed to full height of walls, and turned down on top of same before the backing was placed, dependence being put in the adhesiveness of the waterproofing, and weighting down of top of same while backing was laid. When the backing followed immediately after waterproofing, this scheme worked out all right, but when the backing was delayed, the waterproofing sagged and bulged badly, and in some cases had to be renewed. Hence on walls and elevated railway foundations of another avenue viaduct the waterproofing was carried up in first stage to height of 5 or 6 ft., the work being stuck securely in each stage and backed up immediately.

Due to necessity for transfer of street railway, sewer, water and gas pipes from temporary to permanent supports, during construction of the latter viaduct the floor plate work had necessarily to be finished in some instances within 18 in. to 20 in. of walls and piers, in advance of waterproofing the latter. In such instances the shingle lap method was abandoned and the floor waterproofing was carried through solid against the walls or piers, and when the latter were ready, a six-ply flashing of waterproofing was placed over the angle of floor and wall and extended up the wall, and out on to the floor waterproofing. Over this flashing the wall waterproofing was placed and carried out over full width of exposed floor waterproofing, making a very satisfactory job of solid lap work. Fig. 9 shows the application



SECTION ON LINE W-W.

FIG. 10.

Fig. 9.

Fig. 9-A.

of waterproofing to walls, also flashing of angle of floor and walls in manner last described. Fig. 9-A shows waterproofing in progress on the deck of a viaduct under a street, and is introduced to show the more simple type of viaduct roof work. Fig. 10 shows a cross-section of a cut and cover tunnel.

The principles of application of the waterproof sheets hereinbefore described for other work apply with equal force to this cut and cover work. The writer will, therefore, briefly describe the mode of procedure in the general construction of this work, so that a few points of interest may be brought out, which are partially, though not wholly, related to the waterproofing problem, but which may be of sufficient value to warrant the liberty of a description in this paper. As will be noted by reference to Fig. 10, the tunnel roof is composed of steel girders resting on concrete abutment walls and intermediate columns, all founded on solid rock. The excavation from an average elevation of 10 ft. above the roof was entirely in solid rock, and owing to franchise requirements, together with the fact that a portion of the work encroaches on very valuable private property, it became the engineer's duty to restrict the over-all width of the excavation to a minimum.

The roof of the structure is at an average depth of 20 ft.

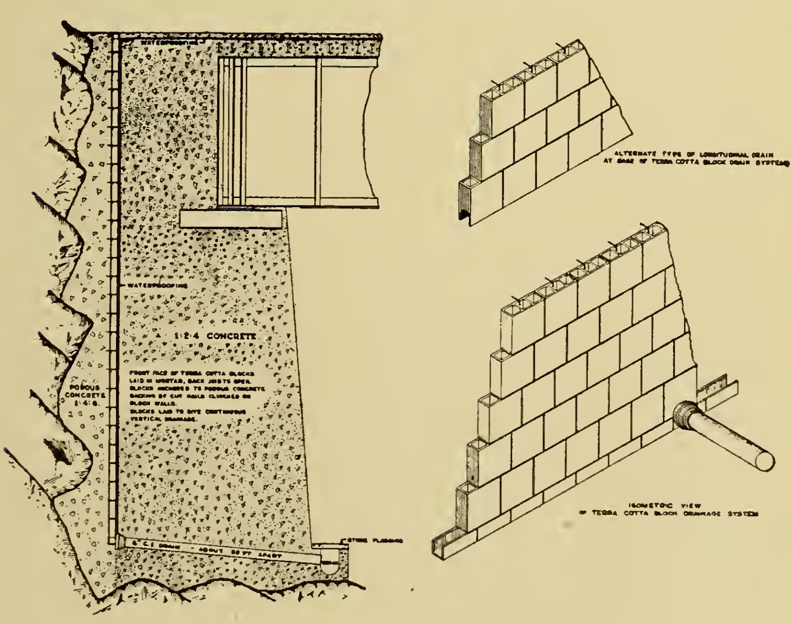


FIG. 11.

below street level and about 9 ft. below sewer level, and the track sub-grade is at an average depth of 49 ft. below street level, 38 ft. below sewer level and 12 ft. below mean high water.

It was apparent that, owing to the above conditions, some surface water and the ground water below sewer level would have to be effectually shut out, and under less restricting conditions the design of abutment walls, capable of resisting hydrostatic pressure due to a head measured from bottom of sewers, might be warranted. After due consideration, however, it was determined to design the abutment walls of suitable section to safely support the vertical loads to be carried by them, trusting to a free drainage scheme to relieve these walls of hydrostatic pressure. The writer devised a free drainage scheme, which is illustrated by Fig. 11, and which, owing to the fact that it has been completed and doing good service for over a year, may be pronounced a success.

The scheme consists merely of the application of well-known materials in a simple but unusual manner, namely, the space from standard section line to ledge, varying from 6 in. to 4 or 5 ft., was filled back of a suitable form to full height of abutment walls with a porous concrete, 1 part cement, 4 parts sand and 8 parts broken stone. This porous backing was faced with hollow, light-burned, porous terra-cotta partition blocks, 12 in. by 12 in. by 4 in., laid with openings set vertically and bonded for continuity of vertical hollow spaces. These blocks were anchored to the concrete backing by cut nails, driven into the latter and clinched over the inner walls of the blocks at joints. The bed joints were buttered in such manner that the back half of the joint was left open as far as practicable and the build joints were similarly made.

This tile drainage sheet was at first footed on a longitudinal tile drain, made by splitting out end cells from the blocks and laying same on bed. Due to the underburned quality of the material many blocks were wasted in an effort to produce one suitable end cell. Hence the type of longitudinal drain was changed to that shown in the upper right-hand corner of the plate. The end walls and partitions of the blocks were chipped out to approximately the form shown, by use of a bricklayer's chipping hammer, and thus the longitudinal drain was obtained with very little waste. This longitudinal drain is connected with a gutter at the toe of the abutment wall, which is, in turn, connected to the underdrainage system. Upon the face of the tiling above described, the wall waterproofing was placed for full

height, with dry laps extended over the backing wall and weighted down. A section at a time, varying from 25 ft. to 50 ft., was thus prepared and the abutment walls completed as soon as practicable after waterproofing.

As may be readily understood by reference to Fig. 10, many months elapsed after waterproofing abutment walls before the roof work was connected and the dry laps were found to be very seriously damaged. The roof work was advanced a section at a time, dependent upon the opportunity for moving equipment, and the roof work sections were of varying areas, and frequently broke part way over the roof. This work was all performed by the shingle method, hereinbefore described, but the patchy procedure on the roof was permitted solely because of the contractor's obligation to make the work tight. The writer is convinced that a better result will be secured if roof or other flat waterproofing is extended full across the work, thereby leaving joints at one edge only.

After the roof waterproofing was completed, it was covered with concrete, varying in thickness from 4 in. to 6 in., and the highways were restored by backfilling over this cover to a height of about 20 ft. So long as the backfilling was kept well back of the end of the completed work, and was stepped off in bench formation, the plain concrete cover served its purpose, but in one case when the backfilling was advanced in bank formation, close upon the completed construction work, the concrete cover broke and the waterproofing was damaged, requiring removal of much backfilling to effect proper repairs. After the occurrence just cited, the writer had the cover reinforced by Clinton wire cloth, and no further trouble was experienced. This reinforced cover was also used on a viaduct roof which was built after the cut and cover tunnel work just referred to had been completed.

Some additional points of interest in the protection of the waterproofing work described herein are the following:

Where excavation for subways below track level was excessive (see Fig. 2), the contractors were not required to fill back solidly against the rock, but were permitted to build 12-in. backing walls of concrete and to backfill behind the latter. They came to the conclusion that much time would be saved by using terra-cotta blocks for backing up subway waterproofing above the 4 ft. wall shown in Fig. 2, and they were permitted to substitute these blocks laid on bed in the usual manner in Portland cement mortar. Recently it became necessary to remodel a section of the subway work, and the adhesion between the terra-

cotta backing and the waterproof sheet proved to be so strong as to require splitting of the blocks in order to remove them.

An 8-in. brick backing was provided for waterproofing on back of viaduct retaining walls under avenues. During construction of one viaduct a settling down and bulging of the backing wall was noted, accompanied by vertical cracks, due apparently to slipping of the backfilling placed against the wall. To overcome the difficulty, the thickness of the backing was changed from 8 in. to 4 in., and a substantial footing was provided, as shown in Fig. 12. No recurrence of the trouble was experienced after the section of the brick backing was modified.

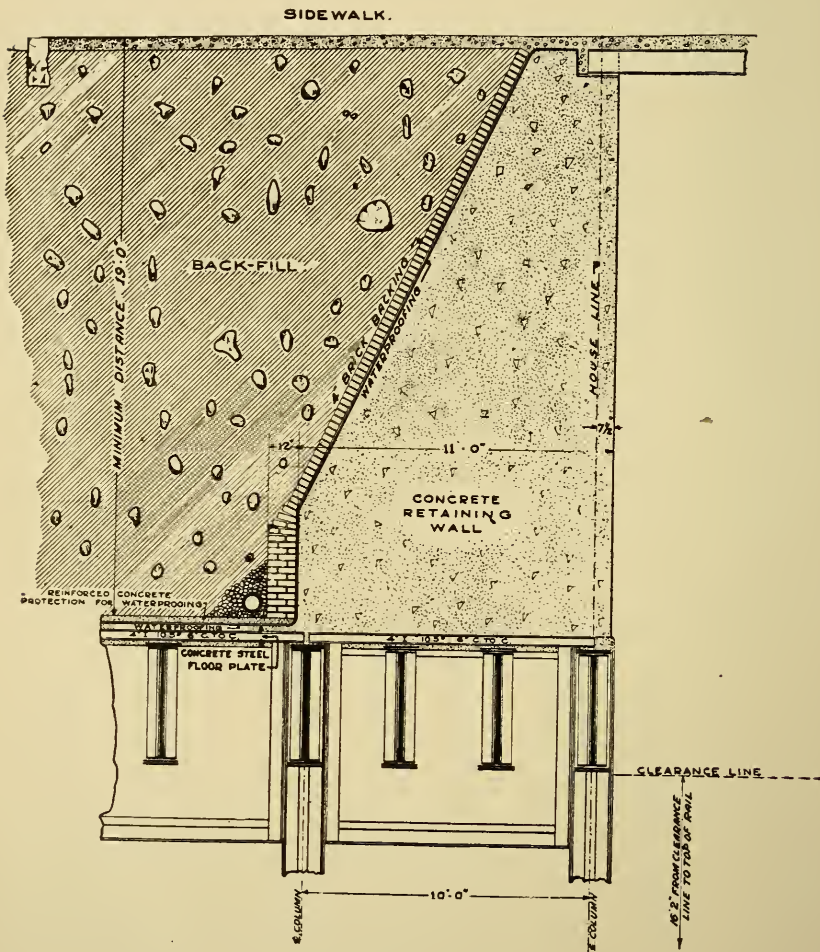


FIG. 12.

Many schemes were tried for substantial protection of stuck lap joints in cases where these had to be left for long periods of time before connecting work could be placed, but the most satisfactory protection was afforded by covering the laps with 2 in. of clean sand.

No special effort was made to obtain better surfaces upon which to waterproof than result from ordinary practice, but the writer believes that it would be worth while to insist on smooth finish for surfaces upon which to waterproof, so that complete adhesion may be obtained and air cushions, bulges, sags and water pockets avoided, in so far as the quality of the surface waterproofed affects these conditions.

When connection of a new to an old section of work is made, the surface of the old work should be thoroughly cleaned by stiff brooms and flexible wire brushes.

The felt used on the work described herein was selected after many comparative tests and analyses had been made for the purpose by chemists, and the requirements adopted as a result of their investigation are as follows:

"The felt must be saturated and coated with asphaltic products and must conform to the following requirements:

"(*a*) The weight per 100 sq. ft. shall be from 12 to 14 lb., saturated, and from 5 to 6 lb. unsaturated.

"(*b*) The weight of the saturation and coating shall be from 1.25 to 1.75 times the weight of the unsaturated felt if coated on both sides, and from 1 to 1.5 times the weight of the unsaturated felt if coated on one side.

"(*c*) The saturation shall be complete.

"(*d*) The ash from the unsaturated felt shall not exceed 5 per cent. by weight.

"(*e*) The wool in the unsaturated felt shall not be less than 25 per cent. by weight.

"(*f*) Soapstone or other substances in the surface of the felt to prevent adhesion shall not exceed .5 lb. per 100 sq. ft. of felt.

"(*g*) The saturating and coating materials shall remain plastic after being heated to 250 degrees fahr. during 10 hr. The coating not to crack when the felt is bent double at ordinary temperature.

"(*h*) The felt shall be soft, pliable and tough when received from the factory and until placed in the work.

"(*i*) The quotient obtained by dividing the tensile strength in pounds of a strip 1 in. wide, cut lengthwise, by the weight in pounds of 100 sq. ft. shall not be less than 7.

"(*j*) The quotient obtained by dividing the tensile strength in pounds of a strip 1 in. wide, cut crosswise, by the weight in pounds of 100 sq. ft. shall not be less than 3.5.

"(*k*) The strength saturated shall be at least 25 per cent. more than the strength unsaturated, taken lengthwise.

"(*l*) The strength saturated shall be at least 15 per cent. more than the strength unsaturated, taken crosswise."

The quality specification for pitch quoted in the fore part of this paper was likewise determined after careful consideration by the chemists.

The pitch used differs from the coal-tar pitch known to the waterproofing trade in New England. It is received on the work in a soft, almost fluid state, and spreads splendidly in average and cold temperatures. It flows too freely in hot weather and does not set so effectively in high temperatures, as the harder coal-tar pitch used for waterproofing in New England. The waterproofers obtained a harder pitch for hot weather work which overcame the objection noted in application. It was at first found to be somewhat unreliable as to quality, but the manufacturers succeeded in making a hard pitch with melting point 110 degrees fahr., which had 36 per cent. free carbon and was considered satisfactory material for hot weather.

It is important that the pitch be not overheated, as it volatilizes and insufficient body remains. The danger of overheating is minimized if a first-class kettleman is employed. Practical tests relied upon by a waterproofer to determine the proper temperature of pitch in the kettle are first to observe whether yellowish fumes rise from the kettle, which are an indication of excessive heating; and second, if the pitch cracks too quickly when spat into, it is too hot, but if a very short interval elapses before cracking, it is heated sufficiently. The degree of kettle heat is wholly dependent upon the grade of coal-tar pitch used. For standing work, the pitch may be advantageously heated much less than for flat work. If heated too much for standing work, it falls away from the mop and much of the body of the coating is lost.

It has been observed that the first coating of pitch will adhere to or coat a concrete surface which is just damp enough to be dustless, better than a concrete surface which is dusty dry. A wet or decidedly moist surface is not suitable for pitch and felt waterproofing. If it is necessary to waterproof a surface which has been under water, the surface should be dried by brooming with sawdust. Cement is sometimes used for this purpose, but the result is not quite so effective and it is a more costly method. It requires from 2.5 to 3 gal. of coal-tar pitch per

mopping for one square, or 18 to 21 gal. per square for six-ply work.

The quantity of waterproofing placed on the work described herein is 1 000 000 sq. ft.

In closing, the writer wishes to call attention to the need of practical inspection on waterproofing work. An experienced waterproofer, familiar with the tricks of the trade, and possessed of the proper temperament for the position of inspector, may readily become a most valued assistant to the engineers in charge.

The engineers for the work described herein are Westinghouse, Church, Kerr & Co., the work being designed and constructed under the immediate direction of the writer, reporting to Mr. George B. Francis, consulting civil engineer.

The writer wishes to acknowledge the faithful service and untiring zeal of Mr. F. F. Skinner, a member of this society, who had direct charge of the work in the field, and Mr. Frank L. Butters, waterproofing inspector, and the many other assistants whose care and skill aided in the accomplishment of the work.

DISCUSSION.

The President, Mr. George B. Francis. — The paper describes only one method of waterproofing, viz., what is known as the membrane method. Two other methods of waterproofing are used to a considerable extent: One known as the integral method, which calls for the introduction of a fine powder to fill the voids in the mortar part of concrete, thus making the body of the concrete watertight of itself; the other known as the adhesive method, which is a waterproof mastic applied to the walls.

The membrane method was, in our opinion, the best method for the work described. The number of ply for such a method is somewhat dependent on the water pressure to be encountered.

In the work described some parts of the sheet were applied for the purpose of damp proofing, which places were drained so that no water pressure ensued; other parts might or might not be under pressure, like the waterproofing of bridge floors, where although no drains were placed, the water might escape at the ends of the bridge by seepage through the ground; and on other parts of the work, which were below sea level, the waterproofing was applied where there would surely be water pressure.

The entire excavated pit for the work which was below sea level was not waterproofed on account of the great expense, but a drainage and pumping system has been installed to care for the same. Certain structures were, however, completely water-

proofed as described, some having water pressures due to 20 to 25 ft. head.

MR. EDWARD W. DEKNIGHT. I have listened with a great deal of pleasure and profit to this very interesting paper by Mr. O'Brien. The paper should be in the hands of every engineer and architect. It goes into important details and intricacies of the practical application of waterproofing based on several years' valuable experience in one of the largest works of its kind in the country, if not in the world. Successful waterproofing depends upon the perfection of details and application, and Mr. O'Brien's experiences and conclusions are valuable because they are based on actual field practice.

Waterproofing is practically a modern art. Not until recent years have architects and engineers paid serious attention to it, as they now must because of the marvelous development of concrete and steel in building construction.

Mistakes in waterproofing are due primarily to three causes: First, use of the wrong material; second, to faulty design; third to imperfect application.

Under the head of material, the paper by Mr. O'Brien deals only with what is known as the membrane method, that is, the use of alternate layers of felt and pitch to form a waterproof stratum, which is practically independent of and apart from the surface waterproofed. In contradistinction is the rigid or integral method, that is, incorporating the waterproofing material with the concrete, or applying to the surface cement plaster, washes, etc. The acceptance and use of either method depends on the opinion of individual engineers and architects. Personally, I have always favored the membrane or elastic method described in the paper.

There is one suggestion regarding materials which occurred to me during the reading of Mr. O'Brien's paper. He stated that in sticking the sheets of felt together, the pitch used was soft at 60 degrees fahr. and melted at 100 degrees fahr., and that, therefore, the pitch had to be somewhat hardened in hot weather. The object, of course, in specifying a pitch of such a consistency was to obtain a cementing material which would not become hard and brittle under ground, estimating the temperature of the earth below grade to be constant at 60 degrees fahr. The important fact, however, was overlooked, that in practical operation it is difficult, if not almost impossible — during the summer months when waterproofing is best done — to use a pitch which is soft at 60 degrees fahr. because at 80 to 90 degrees fahr., as

on a warm day, the pitch will become too soft to hold the sheets together and the waterproofing stratum in place. The suggestion, therefore, that occurred to me is that for sticking the felt sheets together a material should be employed which is not readily acted upon by temperature changes, that is, one which will not run or ooze at 90 degrees, or become hard or brittle at 60 degrees, and at the same time would be as tough and pliable as the felt.

Under the head of design, the following may be noted: Your esteemed president, Mr. Francis, who has had long and wide experience in such matters, has just remarked that the waterproofing on certain walls was not carried across the bottom or under the floor of certain parts of the work. This was because after the water arrived at the foot of the walls, it was led off through drains to sumps, from where it was pumped to the sewers above.

It is a very common mistake on the part of engineers and architects to assume that, because test borings show no water, and that even after the excavation for the foundation is made no water has been developed, waterproofing of the foundation walls and bottom is unnecessary. I have seen buildings erected on the apex of rock hills, the basements of the buildings in the course of a year or less becoming afterward so filled with water as to be like reservoirs, waterproofing having been eliminated on the assumption that as the buildings were on rocky hills no waterproofing would be necessary. Water may develop unexpectedly from hidden springs or from a collection and peculiar drainage of surface water, especially from melting snows in the spring, which may find new channels and gradually work its way toward and into a foundation. Nothing pays better in any structure than to keep moisture and water out of the foundation walls, particularly if the walls contain much steel. In sand or gravel it may not be necessary to waterproof the walls below the footings. In clay and rock it is always desirable that the entire foundation, both walls and bottom, be waterproofed.

The design shown by Mr. O'Brien in the drains for leading the water away from the tunnel wall footings is original and excellent. Also the device for making a watertight joint around the plunger hole in the bottom of the elevator pits. His recommendations regarding felt connections, the brick "backing" or protection for the completed waterproofing and similar details are certainly very valuable.

Under the head of imperfect application the paper shows

clearly the need of experienced labor, and constant and careful supervision. Nothing pays better than good waterproofing, and nothing is more disastrous than imperfect waterproofing. It is very important that the waterproofing work be in charge of an expert waterproofing engineer or superintendent. In fact every waterproofing specification should close with the strict injunction that the waterproofing should be done only by experienced and expert men.

Finally: The idea of placing any waterproofing on the interior surface of a foundation wall is a fallacy. It hardly seems like the exercise of ordinary average intelligence to allow a wall to become damp, wet and saturated through and through when it can be prevented by placing the waterproofing material on the exterior surface of the wall and not on the interior surface. We certainly should not think of doing so in our own residences, where from the standpoint of health it is quite necessary that our cellar and basement walls be as dry as we can possibly get them.

The advanced idea of waterproofing is insulation. No structure containing steel in its foundation, and especially in its foundation walls, can be insulated under the bottom or on the walls by placing any material on the interior surface of the bottom or walls. What will happen when defects and cracks occur in a material so applied under boilers, furnaces, etc.? To prevent electrolysis from affecting the imbedded steel in the foundations of our structures, we must waterproof them from the point of insulation, which can be obtained only by means of an impervious, pliable waterproof stratum on the exterior foundation walls, so that the slightest moisture cannot come in contact with the walls.

[Note. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 15, 1910, for publication in a subsequent number of the Journal.]

DISCUSSION OF PAPER "THE RELATION OF THE STEAM TURBINE TO MODERN CENTRAL STATION PRACTICE."

(VOLUME XLIV, PAGE 103, FEBRUARY, 1910.)

MR. W. H. HERSCHEL. — On page 107 the author says: "Regarding high pressure and high superheat, it should be borne in mind that the percentage increase of available energy given the steam is much greater than the percentage increase in fuel necessary to produce these conditions."

As I understand the author, he is considering only turbine efficiency, so that, assuming a constant efficiency of boiler and a constant vacuum, the available energy would be directly proportional to the fuel consumed, "available energy" being $h_1 - h_2$, the difference between the total heat of the steam at admission and at exhaust. The author, on the contrary, appears to mean by "available energy" that part of the heat at admission which is actually turned into useful work. Therefore, if I understand his sentence correctly, it means that high pressure and high superheat increase the thermal efficiency of a turbine.

There are two kinds of efficiency which are unfortunately not always distinguished. The first is based on the heating value of the fuel and is the ratio between the number of heat units converted into useful work and the number which would result from complete combustion. This is called the thermal efficiency of the plant, because it depends on the boiler and condenser, as well as on the engine or turbine.

The other efficiency, which has a much higher value, depends on the turbine alone and is the ratio between the number of heat units converted into useful work and the total number available. I shall call this the "potential efficiency," which is one of the shorter of the many names which have been suggested.

The theoretical consumption, in pounds per brake horse-power, per hour, is obtained by dividing 2 547 by the number of British thermal units available, this available energy being most easily obtained by scaling from a total heat-entropy diagram. The theoretical consumption, divided by the actual consumption, gives the potential efficiency, which is evidently quite a different thing from economy or water rate. The number of pounds per unit of power, per hour, will decrease; that is, the economy will

improve with an increase in the number of heat units available if the potential efficiency remains constant, and it may even improve if the efficiency decreases slightly. In testing turbines, high pressures, high superheats and high vacua are usually employed in order to get as low a water rate as possible, but the lowest water rate does not always indicate the best efficiency.

The actual gain from superheat is more than the theoretical, that is, superheat will increase the potential efficiency of a turbine. The actual reduction in water rate for 100 degrees fahr. of superheat is about 10 per cent. instead of about 8 per cent., as would be expected from the increase in total heat of the steam at admission. The efficiency is nearly constant with a variation in vacuum, the water rate varying inversely as the number of heat units available. On the other hand, the gain from an increase in admission pressure is less than the increase in the total heat. In the neighborhood of 150 lb. per square inch gage pressure, the theoretical gain would be about 2 per cent. for 15 lb. increase of pressure, whereas the actual gain is about 1.5 per cent., and the higher the pressure, the greater the difference between the theoretical and the actual gain.

Tests on a 500 kw. turbine of my design, in which a water brake was employed, clearly showed this decrease in potential efficiency with an increase in admission pressure. The highest efficiency, over 72 per cent., was obtained with an admission pressure of 9.75 lb. per square inch absolute, with the high pressure running wheels of the rotor removed, while the best economy was obtained with the highest admission pressure, 150 lb. gage pressure and with the complete rotor.

The potential efficiency is a measure of the success of a turbine designer in dealing with certain prescribed conditions of superheat, pressure and vacuum, but it does not show whether these conditions are advantageous from the point of view of the operating engineer. The value of the turbine to him is measured more nearly by the thermal efficiency based on the total heat of the steam at admission, which would be the thermal efficiency of the plant in case the boiler efficiency were 100 per cent. If the water rate, in pounds per brake horse-power, per hour, is called W, then the number of B.t.u. utilized per pound of steam will be $\frac{2\,547}{W}$. The total heat of the steam at admission is h_1 but the heat of the boiler feed water being q, the heat necessary to produce steam at admission conditions will not be h_1 but $h_1 - q$. When the condensed steam is used for boiler feed water, q be-

comes q_2, the heat of the liquid at exhaust, and the heat required to produce steam at admission conditions will be $h_1 - q_2$. The thermal efficiency of the turbine will then be $\frac{2\,547}{W(h_1 - q_2)}$.

This formula may be derived in another way. The efficiency of the Carnot cycle is $\frac{T_1 - T_2}{T_1}$. The efficiency of the actual engine cycle as compared with the Carnot cycle is $\frac{(h_1 - h_2)T_1}{(h_1 - q_2)(T_1 - T_2)}$ and multiplying this by the efficiency of the Carnot cycle we get $\frac{h_1 - h_2}{h_1 - q_2}$, which would be the thermal efficiency of a plant with 100 per cent. boiler and turbine efficiency. Multiplying this by the potential efficiency of the turbine, we get

$$\frac{(h_1 - h_2)}{(h_1 - q_2)} \times \frac{2\,547}{W(h_1 - h_2)} = \frac{2\,547}{W(h_1 - q_2)}$$

which is the same value of the thermal efficiency of the turbine as was previously obtained.

This shows that the potential efficiency is a factor in determining the thermal efficiency and that consequently a decrease in potential efficiency with an increase in pressure tends to cause a decrease in the thermal efficiency; but an actual decrease can only occur in case the increase in the factor $\frac{h_1 - h_2}{h_1 - q_2}$ is more than counterbalanced by the decrease in the factor $\frac{2\,547}{W(h_1 - h_2)}$.

I find roughly that for an increase in admission pressure from 150 to 250 lb. gage, the first of these factors will increase about 8 per cent., but on account of the decrease in the second factor, the net gain will be only about 3 per cent. It therefore becomes doubtful whether an admission pressure of much over 150 lb. is desirable on grounds of economy of coal, for over against the small gain of 3 per cent. in thermal efficiency must be considered the increase in first cost and operating expenses due to the higher pressure.

It seems to me that the chief advantage of high pressures is that they enable a large power to be obtained from a comparatively small sized turbine, an increase of admission pressure from 150 to 250 lb. increasing the power about 68 per cent. At any rate the advantages of high pressure are quite different from the advantages of superheat, and it seems to me that there is danger of causing confusion by classifying them together.

If the author, contrary to my understanding, meant to imply that the boiler efficiency increased with an increase in pressure or in superheat, I am sure there are others besides myself who would be glad to have the evidence presented.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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RECENT DEVELOPMENTS IN WHEEL TESTING AT PURDUE UNIVERSITY.

BY CHARLES H. BENJAMIN.

[Read before the Engineers' Club of St. Louis and the American Society of Mechanical Engineers, March 12, 1910.]

BEFORE proceeding to describe the recent testing pit which has been established at Purdue University for experimental work in bursting various rotating members by centrifugal force, it will perhaps be well to review the progress made in this kind of experimentation since the first work which was reported to the Society in 1898. At that time, the object was to determine the bursting speed of small model fly-wheels with different types of rim and joints.

The first wheels experimented on were 15 in. in diameter and were rotated by means of a Dow steam turbine, the speed being measured by an electric commutator. The shield used was made of 2-in. pine plank weighted with heavy castings and timbers.

Fig. 1 shows the appearance of the shield after the first explosion. For succeeding experiments a similar shield made of 6 by 12 in. white oak was constructed. An increase in the size of the wheels tested to 24 in. resulted in the complete wrecking of this shield as may be seen by Fig. 2. In all further experiments conducted that year, the shield was made of oak timbers 12 in. square, firmly bolted together and covered with 3-in. oak plank. The speed of the flying fragments is indicated by the fact that some of them cut clean holes through moving belting similar to

those which would be made by bullets. During this year, ten 15-in. and seven 24-in. wheels were broken.

Further experiments on 24-in. model wheels were made during the following year and sixteen wheels were broken. The wheels in this series of experiments were enclosed in a cast-steel ring 36 in. inside diameter, and with a rim section of 4 by 6 in. This was lined with wooden blocks to absorb the energy of the fragments and was completely enclosed in oak planking. The same steam turbine was used for driving pulleys, but a tachometer wa sused for counting the speed. The appearance of the casing and wheel after an explosion is shown by Fig. 3. After an explosion of this character, the wooden blocks would move around in the ring several inches, showing the tangential motion of the fragments. That this apparatus was not entirely safe was demonstrated in one of the experiments by the escape of portions of the pulley rim from the casing, due to the breaking of the retaining bolts. Although there were numerous spectators in the room, no accident occurred.

In this same apparatus were burst fifteen emery wheels of different makes, as reported to the society in 1903. On account of the greater fragility of the emery wheels, no accident resulted.

These experiments were followed in the succeeding year by tests on wooden and steel pulleys 24 in. in diameter. The results of these experiments were published in August, 1905, in *Machinery*. Eight pulleys were tested, including five wood-split pulleys, one with steel arms, one all-steel pulley and one wooden pulley with a solid web which we did not succeed in breaking. Quite a number of pulleys made of paper fiber were tested in the same way, the results not being very different from those on wooden pulleys.

In 1906 and 1907 a large number of cast-iron disks of various thicknesses and types of hub were exploded in the same apparatus. The results of these experiments and conclusions from them have not yet been published.

It seemed desirable that larger pulleys should be tested in the same manner to see if the peripheral bursting speed would be the same for different sizes of pulleys. A few experiments were made in 1904 on pulleys 4 ft. in diameter. Former experience showed that it was hardly safe to burst pulleys of this weight and size inside a building, and the apparatus shown in Fig. 4 was built entirely of steel and was 5 ft. inside diameter. The shield was of rolled boiler plate $1\frac{1}{4}$ in. thick and having a tensile strength of 65 000 lb. per sq. in. Flat plates $\frac{3}{8}$ in. thick were

Fig. 1.

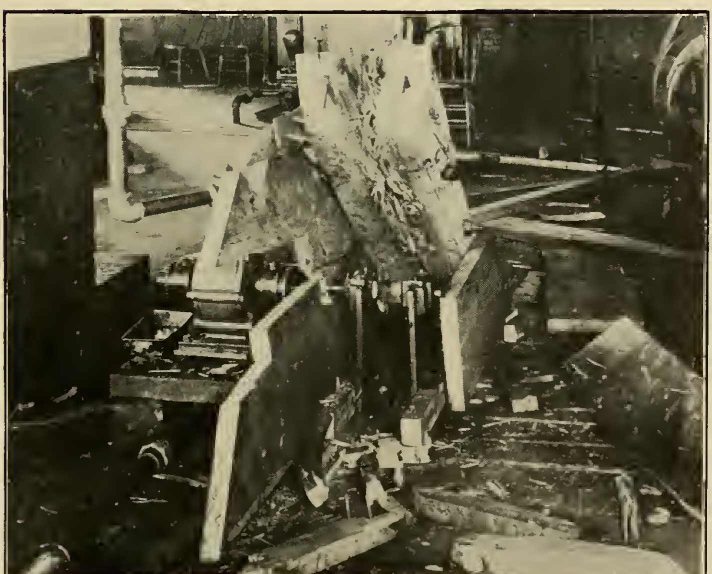


Fig. 2.

Fig. 3.

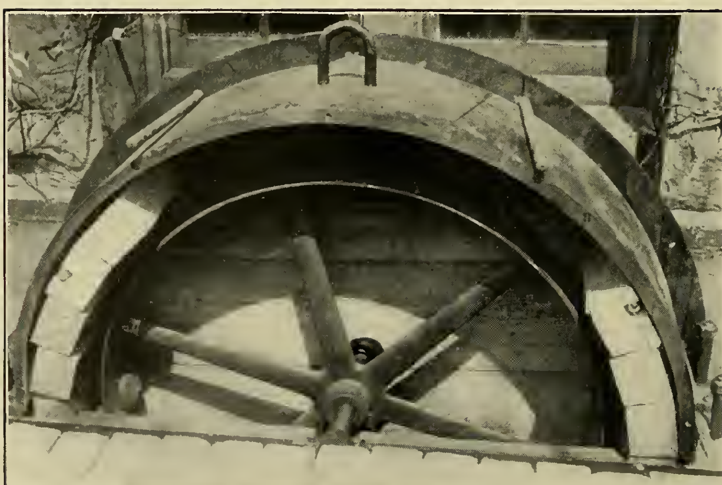


Fig. 4.

bolted to the sides so as to completely enclose the wheel tested. Without going into the details of these tests, it will be sufficient to call attention to Fig. 5 showing the shield after the explosion of the third wheel. It is enough to say that the upper half of the casing, weighing about half a ton, was carried 75 ft. in the air and some hundred feet in a horizontal direction.

About this time, the attention of the writer was called to the fact that a German experimenter had been using a vertical shaft for bursting emery wheels, mounting the wheel at the lower end of the shaft inside a pit. The simplicity and safety of this form of construction were strong points in its favor. The last testing apparatus devised has been constructed on this principle and is located at Purdue University. Fig. 6 shows a vertical section of

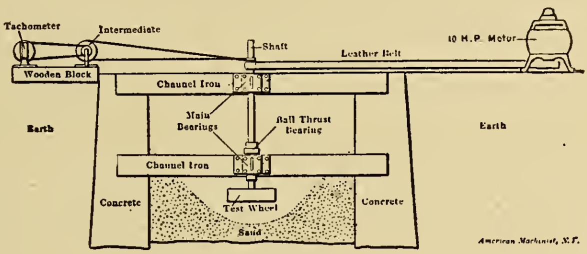


FIG. 6.

the pit and connections and needs little explanation. The weight of the wheel and shaft is supported by a ball and thrust bearing, while rotation is effected by a 10 h.p. motor having a speed which can be varied from 800 to 2 400 rev. per min. The pit itself is lined with concrete, but the impact of the fragments is received by a bank of sand. This works admirably and prevents any bruising or smashing of the fragments after the explosion. The speed is taken in the usual way by a tachometer.

During the winter of 1908–9 this apparatus was used very successfully in testing the strength of certain pulleys.* These pulleys were sixteen in number and were all 24 in. in diameter with rims from 6 to 6¾ in. wide. The material used in their construction was wood, cast iron, paper and steel. Some of the rims were solid, but most of them were of the usual split-pulley type (Fig. 7). The linear bursting speed of the solid wooden pulleys was about 275 ft. per sec., equivalent to 2 600 rev. per min. The linear bursting speed of the split pulleys varied from 220 to 260

* These experiments were made by Messrs. Biggs and Woodworth, senior students, as a part of their graduating thesis.

ft. per sec., or from 2 100 to 2 600 rev. per min. The paper pulleys, on the other hand, having a solid web, were considerably stronger, averaging about 300 ft. per sec. linear bursting speed, or nearly 2 900 rev. per min. (Fig. 8.) Contrary to the usual opinion, the steel wheels are no stronger against bursting than the average wooden pulley. In fact, they are somewhat weaker than a well-constructed pulley made of wood. Two wheels tested burst at exactly the same speed, 2 240 rev. per min., or 235 ft. per sec. The weakness of this type of pulley is due to the peculiar form of joint fastening which is bent and broken by the centrifugal pressure. (Fig. 9.) The bursting of the wooden pulleys was due in most cases to the balance weights consisting of slugs of round iron which were inserted in holes bored in the rim. The greater density of these caused considerable centrifugal force at the points where they were located. It was evident from the appearance of the broken wheel that some of these weights had forced their way through the rim, thus starting rupture. (Fig. 7.)

It is difficult to see how ordinary pulleys with wooden rims can be satisfactorily balanced without weakening them. As, however, there is rarely necessity for a linear speed of more than 100 ft. per sec. all of the pulleys tested had a sufficient factor of safety for commercial use. This is not true, however, of all pulleys. Two 4-ft. pulleys which were tested burst at speeds respectively of 1 100 and 600 rev. per min. which was considerably less than was to have been expected. In the case of the pulley having a solid rim, this was due to the presence of a balance weight inside the rim weighing 3½ lb. At 1 100 rev. per min., the centrifugal force of this balance weight would be over 2 700 lb. In the same manner 4-ft. pulley No. 2 was burst by the centrifugal pressure of a flange which weighed with its bolts 7½ lb. and had a centrifugal force at bursting speed of nearly 1 700 lb.

The effect of a joint flange is particularly disastrous on account of the weakness of the joint itself to resist bending.

In conclusion, I may say that the bursting speed of most cast-iron pulleys having continuous rims may be put at about 400 ft. per sec., corresponding very nearly to a centrifugal tension of 16 000 lb. per sq. in. A wooden pulley with a continuous web and rim is even stronger than this since wood is stronger in proportion to its weight than cast iron. A 2-ft. wooden pulley of this description has been run at a speed of 467 ft. per sec. without breaking. The ordinary split pulleys, whether of wood, steel or iron, cannot be relied upon at speeds much over 200 ft. per sec. on account of the weak points which have been before

mentioned. For experimental high speeds, steel pulleys could undoubtedly be constructed which would have a much higher bursting point. The poor joint design of the ordinary split-steel pulley, such as is used for shafting transmission, renders it unusually weak in this respect.

It is proposed to use the testing pit for further experiments along several different lines, one being the testing of various kinds of grinding wheels, including carborundum and also the ordinary wet grindstone. It is hoped, also, to test our several fly-wheel joints on model wheels ranging from 4 to 6 ft. in diameter. I hope to have an opportunity some time of testing some band saw wheels in a similar manner.

Table showing Data and Results of Experiments Made in the New Testing Pit.

No. of Test.	Kind of Material in Pulleys.	Rim.				Weight in Pounds.	Bursting Speed.	
		Style.	Diam. in Inches.	Breadth, Inches.	Depth, Inches.		Rev. per Minute.	Peripheral Speed = V Ft. per Sec.
1	Wood	Solid	24	6.25	1.62	29·37	2 720	284·7
2	,,	,,	24	6.25	1.62	29·37	2 550	266.9
3	,,	Two sections	24	6.5	1.78	29.67	2 210	231.8
4	,,	Two sections	24	6.5	1.78	29.67	2 110	220.8
5	,,	Two sections	24	6.5	1.78	28.81	2 390	251.0
6	,,	Two sections	24	6.5	1.78	28.81	2 430	254·3
7	,,	Two sections	24	6.5	1.78	28.81	2 360	247
8	,,	Two sections	24	6.5	1.78	28.81	2 420	253·3
9	,,	Two sections	24	6.5	1.78	28.81	2 570	258.5
10	,,	Two sections	24	6.5	1.78	28.81	2 535	244·4
11	Cast iron	Solid	24	6.0	.406	70·44	3 720	389·4
12	,,	,,	24	6.0	.406	70·44	3 380	353·8
13	Paper	,,	24	6.0	1.75	77·37	2 820	295·2
14	,,	,,	24	6.0	1.75	77·37	2 930	306.7
15	Steel	Two sections	24	6.75	.0625	41·75	2 240	234·5
16	Steel	Two sections	24	6.75	.0625	41·75	2 240	234·5

DISCUSSION.

Mr. G. M. Peek. — I would like to ask if there was any trouble with the shaft, the driving shaft that the pulleys were on, so that it had to be renewed.

Professor Benjamin. — It required a new shaft usually.

Mr. Peek. — For each experiment?

Professor Benjamin. — Yes. That is, the shaft is usually sprung by the pulley being out of balance, — rotating after it is out of balance, — and of course all mechanics know that after a shaft is once sprung you can never make it straight again.

Prof. H. Wade Hibbard. — I begin to be frightened about some experiments we are going to perform this spring at the Missouri State University on aeroplane propellers. We propose to run some propellers made of wood, 6 ft. in diameter, at 600 to 1 800 per rev. min., and I would like to inquire whether we should be wise to erect at least an oak bomb-proof for that experiment. We were intending to perform the experiments right in the laboratory, but I begin to be afraid we are taking some risk.

Professor Benjamin. — I think the best example of aeroplane work was that which I did outdoors. [Laughter.] I think it would be extremely unsafe to make any experiments of that kind unless the apparatus was very carefully enclosed in some strong material. It does not make much difference what the material is, if it is going 200 to 400 ft. per sec. it is vicious, and in some of these experiments fragments of wood go right through a belt just like a bullet. When the belt is moving or running, the wood goes right through it, making a clean hole. Now, when you deal with velocities of this kind it doesn't make much difference what the material is, and, in fact, theoretically you can run a wooden pulley faster than a cast-iron pulley without bursting if the joints are all right.

Colonel Meier. — I would like to ask about the aeroplane propellers. You wouldn't have any rim there, and the grain would run opposite; you would have to split according to the grain.

Professor Benjamin. — The stronger it is, the more dangerous; no doubt about it.

Colonel Meier. — Yes, I know it would probably run at a higher speed.

Professor Benjamin. — That is the difficulty, and almost any speed at which such members break is dangerous to human life.

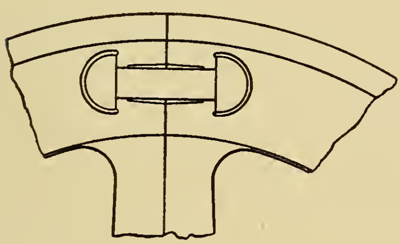
Professor Hibbard. — It is not intended that we should burst these aeroplane propellers. They would only be run at the speed at which planes are run in practice, in actual aviation. And under those conditions are we at all near the danger point where we ought to put a bomb-proof in our laboratory?

Professor Benjamin. — What is the peripheral speed?

Professor Hibbard.— Two- or four-blade propeller, diameter about 6 ft., each propeller about 2 ft. long and running about 1 500 to 1 800 rev. per min.

Professor Benjamin. — You wouldn't want to be anywhere around while you are doing that. My point is, that the peripheral speed would be a very dangerous one, and if anything did get away it would be very dangerous. Of course, if you knew it was not going to break, you would not have to test it, but if anything does give way at that speed it would be very dangerous to human life. You would find that you have a speed in excess of most of the speeds that I have mentioned.

Mr. J. D. Macpherson. — Have you ever investigated the construction of split arms — making the joint through two of the arms? We make fly-wheels in that manner now, large fly-wheels with heavy arms, and we split the wheel along the center of two arms and then dovetail one side into the other, and then have prisoners on either side of the rim. That would take away the added weight from the joint.



FLYWHEEL 9'-6" FACE-14" RIM WEIGHT 11500LBS

Here is a sketch of it; with a heavy arm and heavy rim and the joint over the arm dovetailed in this manner. You see that removes the feature of having the weight of the joint midway between the arms.

Professor Benjamin. — I would say in regard to that, that theoretically it is almost a perfect joint. If you calculated the area of metal through this point and divided it by the area of metal anywhere through here (indicating), that would represent the efficiency of the joint, assuming that this split was as strong as the rim, which it would not be, of course. Now, there can be no bending action of any consequence. It is purely centrifugal force, direct pull, so that there would be no tendency to open that joint, and you could get almost any efficiency you wanted there up to 80 or 90 per cent. The development in the construction and design of fly-wheel rims has changed very much since these experiments were inaugurated and since these discussions were held in the American Society of Mechanical Engineers. Mr. Stanwood is a man who has been very active

in this matter, and also Professor Lemsler, and it has resulted in most companies putting the joint over the arm in some way instead of between the arms.

Mr. V. Hugo. — I would like to ask Professor Benjamin what he considers the greatest allowable strain in the rim of a cast-iron wheel?

Professor Benjamin. — Cast-iron wheels with solid rims, that is, having no joints in the rim, have been burst, a large number of them,— I do not remember how many, — and the linear speed varied from about 390 ft. to 420 ft. per sec. This would give a centrifugal tension, assuming there was no bending, of about 16 000 lb. to the square inch. Now, of course, you can get any factor of safety you please. Running at one half of that speed you would have a factor of safety of four, so that in the ordinary pulley with a solid rim it would indicate there is no appreciable bending in the spokes.

Mr. Hugo. — One reason for the question is that a great many manufacturers say their wheels are safe up to a speed of 6 000 ft. a minute and in the same breath they say that the tension does not exceed 1 000 lb. Now, if your flange joint has an efficiency of only 25 per cent., which you have shown to be the case, that would indicate a tension in the rim of 4 000 lb. Would it not be 4 000 lb. in that case?

Professor Benjamin. — Why, the centrifugal force varies as the square of the speed, so that if you double the speed you quadruple the centrifugal force. A pulley 2 ft. in diameter, a cast-iron pulley, would burst at about 4 000 revolutions, which corresponds very closely to 400 ft. per sec., and if you run that pulley at one half the speed, you get a factor of safety of four. In other words, the tension instead of being 16 000 would be 4 000. I cannot answer your question offhand without a little calculating in regard to those particular figures, but the factor of safety would be as the square of the speed ratio.

Mr. H. A. Ferguson. — I would like to ask Professor Benjamin if he has made any experiments in friction cutting disks, such as are used in modern sawing machines. I have been interested for several years in such machinery, and I know that some of the speeds that have been used have been terrific as compared with those shown to-night.

Professor Benjamin. — What kind of disks were those?

Mr. Ferguson. — Open-hearth flange steel. One machine that I designed, running in Chicago, has a shaft speed of 1 988 rev. per min. with a 52-in. disk, $\frac{3}{8}$ in. thick, giving a

peripheral speed of about 26 000 ft. per min. Now that machine has been running to my knowledge four and a half years, with a change of disk every month or six weeks, and I never knew any tendency to break. There have been hundreds of machines of similar capacity, with ¼-in. thick flange steel disks, 42 to 44 in. in diameter, running with a peripheral speed of 22 000 to 23 000 ft. per min. That is ordinary practice in friction cutting, and from what you have given us to-night I imagine we are getting somewhat close to the danger point at 27 000 feet.

MR. BRYAN. — What is the purpose?

MR. FERGUSON. — Cutting structural steel.

MR. BRYAN. — Cold?

MR. FERGUSON. — Yes, cold. I think in Mr. Meier's shop here in St. Louis he has one of recent design that runs about 22 000 ft. per min. It is hollow ground and accurately balanced.

PROFESSOR BENJAMIN. — Not very much is known experimentally about the bursting speed of disks. Of course a disk is stronger than a ring, because the centrifugal tension is distributed all the way through. That is, the web helps to hold. The most reliable theoretical work on that subject is probably in Stodola's "Steam Turbines," and he gives us a certain speed for a solid disk such as the De Laval people use. That is welded right on the end of the shaft and has no hole in it, and he states, I believe, that the bursting speed, if there is a hole in the center of the disk, would be about one half that permissible when there is a solid web. I never believed that, although it works out beautifully by calculus. [Laughter.] In other words, the difference between a pin-hole and zero is two. [Laughter.] I have made quite a large number of experiments on cast-iron disks, but not enough to give any formula. The bursting speed, however, is much higher than it is for rings. Now 27 000 ft. per min. would be 450 ft. per sec., which would burst any cast-iron ring. But a cast-steel ring, having a strength — we will say a tensile strength — four times as great, would require double that speed to burst at, and as a disk might require a great deal more, there would not appear to be any danger in the speed you mention in steel disks.

MR. FERGUSON. — At the Homestead Mills, Cambria Steel Company, and at the North Works of the Illinois Steel Company those disks are balanced by punching holes in them. I have seen them with as high as twenty holes in them at any distance — that is, no particular calculated distance from the center. The man who does the balancing is an ordinary mechanic. He simply

lays the disks on a table, describes a rough line and takes punchings just the thickness of the disk and sticks them on the disks with beeswax on that line until he gets them balanced, and then he punches holes in the opposite side, and that is the way they are balanced. Those I am referring to were made by a saw maker and were hollow ground and balanced without any hole.

Professor Benjamin. — I think that would be a risk I should not want for myself.

Mr. Charles E. Jones. — I asked Mr. Ferguson aside here why he changed those disks so frequently, and he replies that he finds that they begin to split along the periphery, and is obliged to take them out. I would like to ask whether it is incipient failure that causes them to be taken out, or whether it is due to the heat generated in the cutting action.

Mr. Ferguson. — It is due to the heating and cooling; due to the crystallization that takes place on the edge of the disk.

Professor Benjamin. — Of course, we must remember in that problem that there is very severe strain on the fibers of the disk at the outer edge, due to the cutting action, that is not calculable, and might result some time in wrecking the disk, causing a failure, in combination with the centrifugal force.

Colonel Meier.— I shall be very careful how I walk around that saw. I will say, Professor Hibbard, I think it would be advisable if you built one of those concrete bomb-proofs, and while you are making those experiments test some of the aeroplane propellers to destruction, so as to find out what factor of safety they have. I think those gentlemen are taking a great risk. I would not like to go up with them.

Mr. Peek. — I would refer to those saws — if they were dished or cut plain?

Mr. Ferguson. — The saw maker puts a slight tension in them — just what they are I do not know. There is no dish put in them, however. There is put in what they call a tension;. no dishing at all.

Colonel Meier. — They are hollow ground, so as to make the outer edge slightly thicker.

Mr. Ferguson. — The outer edge is slightly thicker than the center.

Mr. Bausch. — This paper of Professor Benjamin's has certainly been very interesting and instructive, and I have been sitting here and wondering, when he was describing those experiments, what would happen to a person in going into a power plant when the governor belt suddenly broke. I shouldn't want

to be very close to that fly-wheel or within range of it, in using such speeds as he has been describing. I was just wondering what experiments could be made, how you could get at it, to make such a bomb-proof as will put you near some of those big fly-wheels and find out something about them. I am sure I never had any experience, but have been considering myself fortunate not being close to those wheels when they did go to pieces.

Professor Benjamin. — I think that four feet is about the limit of my endurance. I never went any closer. [Laughter.]

Colonel Meier. — That seems to be the difficulty about all such experiments, that you cannot make them by a private institution in sufficient size. Now the problems, of course, in regard to fly-wheels do not come up with the 4-ft. wheels, but deal with the 10-ft. and 12-ft. sizes. Those experiments can only be done at government expense, and I think that when we get stronger in the engineering profession, when we get more united, we ought to make our influence felt, to get the government to undertake a great number of experiments, or to have them done at the government expense at the various institutions equipped to do it. The government has been doing some splendid work since 1904 in coal testing, both under boilers and in gas engines, and we have got information in that way we could not get any other way.

Now, returning to the fly-wheel, there is a gentleman present who has a great many fly-wheels running in this neighborhood, and I have always felt perfectly safe in being around them. I want to ask how he got at it? He must have had a way of getting at it. I call on Mr. Krutsch.

Mr. Krutsch. — Well, I haven't burst any, and I hope that I never will. [Laughter.]

Colonel Meier. — Well, is it your secret, Mr. Krutsch, or do you want to tell us how you do it?

Mr. Krutsch. — Don't run them too fast. [Laughter.]

Colonel Meier. — Mr. Smith, have you anything to add to this discussion on fly-wheels?

Mr. Jesse M. Smith. — I just want to say a word in regard to high-speed disks. The disks of the size which the gentlemen have spoken about have been in use many, many years in iron and steel works, and occasionally they go to pieces, but not often; but the gentleman speaks of running these disks at 27 000 ft. per min. That is only 450 ft. per sec., and I understand it is common practice, even in the largest steam turbines, to

run disks at 500 ft. per sec. I happen to know about that in some investigations I have been making recently, and that leads me to make this statement.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1910, for publication in a subsequent number of the JOURNAL.]

SMALL STEAM TURBINES.

By John Gurney Callan.

[Read before the Boston Society of Civil Engineers, November 18, 1908.]

A designer and manufacturer of steam turbines was confronted at the beginning of his work by an essentially commercial problem which required solution by engineering means. Entry had to be made, with new apparatus, into a field already occupied by that which was well understood and, in most respects, satisfactory and adequate. A criterion and level of excellence was established thus which it was necessary to surpass in at least some degree if a useful purpose was to be served and a market commanded.

The relative importance of one or another desirable characteristic is in considerable measure a function of size of unit, and since the technical difficulties surrounding the achievement of these several desiderata is also a function of size — albeit quite a different function — it was found that the terms of the problem presented to the designer of a commercially successful line of small turbines assumed rather widely different values from those met in the design of large turbines.

We may properly consider first the commercial requirements which formulated the question before the designer, then the technical features and considerations which shaped his answer, and finally examine some available examples of representative small turbines, with a view of comparing attainment with aim, and thereby finding how considerable a service to the engineering community has been rendered by the machines thus analyzed. To define our field, we may arbitrarily call turbines of less than 500 k.w. small, and consider only those fields of activity in which turbines ordinarily find their application.

In general, it is obvious that, at a given horse-power, current price and performance furnish two coördinates from which a curve may be drawn or imagined as a basis of comparison at that power; and that a commercial designer must work on turbines, as elsewhere, with something of this nature constantly in mind if he would escape the false values which arise from

optimism, enthusiasm and the fascination which a new conception exercises upon the inventive faculties.

Inherently, the turbine possesses the ability to directly produce rotary motion with high theoretical economy and without fundamental drawbacks, and this fact at once furnishes *prima facie* evidence that it should eventually become the driver of all high-speed steam-driven machinery, provided it does not in any important respect fall below the standards established by best current practice. Many delays, disappointments and incidental troubles were to be expected in the development of a difficult new art such as this has been, and time has been and will be required for the turbine to establish its superiority even in those fields to which its characteristics pre-eminently adapt it, but we may be sure that in those fields or environments where it is fittest, it will inevitably survive the less fit types.

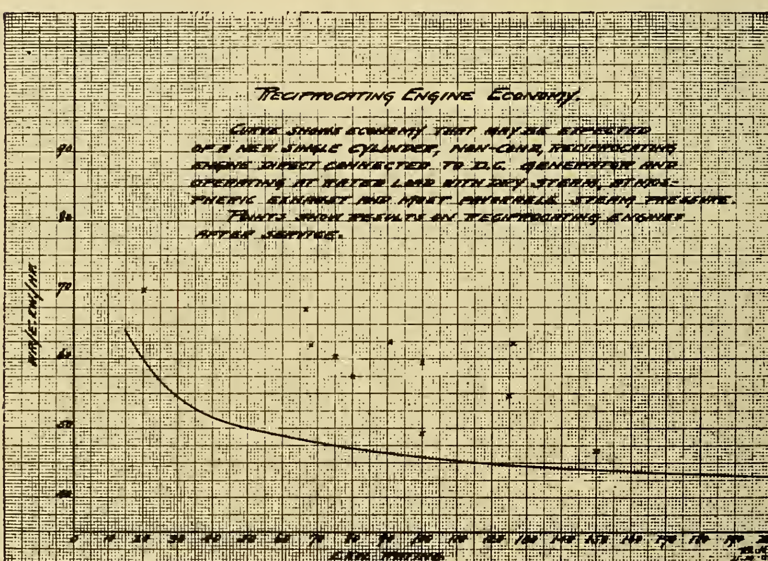


FIG. 1.

A prime mover should be judged on original and maintained economy, first cost, simplicity and reliability, maintenance and depreciation, attendance, use of oil and minor supplies, size and weight, cost of foundation, of housing and auxiliaries. The reciprocating steam engine had so long served the public that it became the natural pacemaker. It was necessary,

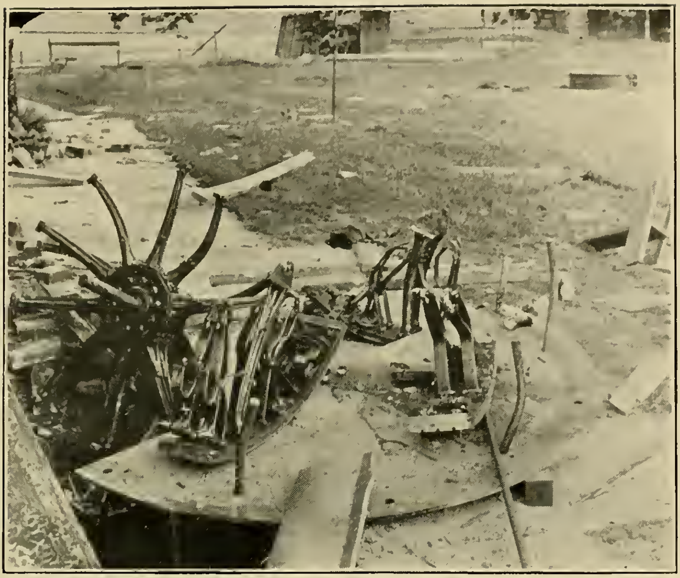


Fig. 5.

Fig. 7. Wooden Split Pulley.

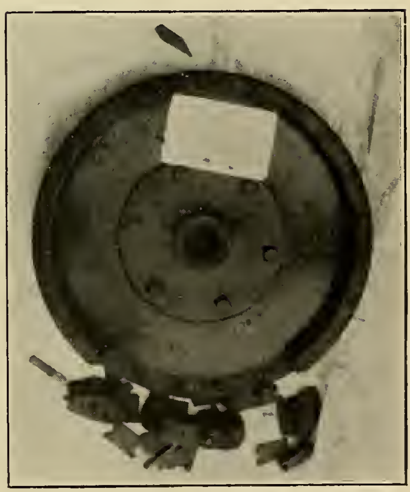


Fig. 8. Paper Pulley.

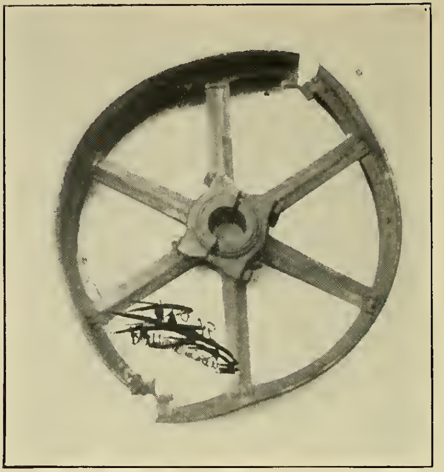


Fig. 9. Steel Split Pully.

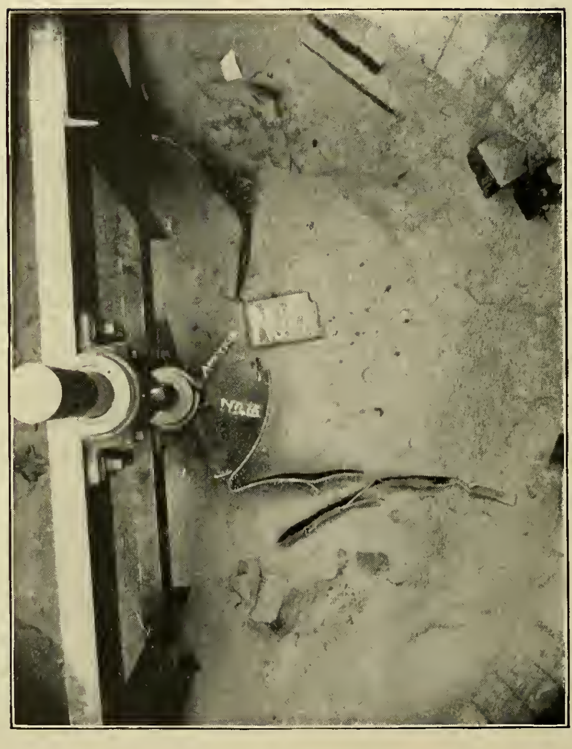


Fig. 10. View looking down into Pit.

therefore, for the designer first to examine the performance of equivalent types of reciprocating steam engine in respect of these particulars. Current prices furnished further data as to the amount available to be spent in achieving the necessary results.

In the matter of engine economies, much interesting information is available, both upon new engines and upon those which have been for some time in service. A curve was prepared by one of the large turbine manufacturers showing economies of new non-condensing, single-valve engines of small capacity. This curve is shown in Fig. 1. It was compiled from a very considerable number of tests, and was originally plotted for the information of engineers of the turbine company, to be used in comparison with turbine results.

Some unconnected points shown on the plot represent careful tests of certain engines of similar type after various moderate periods of service under average conditions. These indicate in a general way the depreciation which may be expected with such reciprocating engines after some length of service under fair commercial conditions. It will be of interest to note that turbines of first-rate design do not suffer such depreciation.

This curve was drawn after careful averaging of a large number of results and possesses a certain degree of interest even when considered apart from the data upon which it is founded. Extremely elaborate reciprocating engine statistics, and curves of this general character applying on performance of large engines, were prepared by certain German turbine manufacturers, but it would transcend the scope of this paper to go further into these statistics.

With some of the other criteria, absolute statements and tables would become cumbersome, and some general comparisons, although somewhat ahead of their logical place in this paper, will be substituted. The nature of many of these comparisons leads to their expression in general rather than statistical form; they are, however, of course, ultimately based on statistical information.

Tables of prices would be obviously out of place in a paper like this. In general, small turbine prices are competitive.

In the matter of auxiliaries, small independent condensing turbines require the same expenditure as do equivalent reciprocating engines working on the same vacuum. Should it be

decided to take advantage of the ability of the turbine to profit by higher vacua than can a reciprocating engine, then somewhat larger condenser and auxiliaries will be required to obtain these higher vacua. With non-condensing horizontal turbines, or those which exhaust into a previously existing condenser, there are no auxiliaries.

In the matter of size and weight, the normal turbine always shows advantage — and usually marked advantage — over normal reciprocating designs. This is also the case as to maintenance and depreciation, attendance, cost of foundation and housing, and of minor supplies, while in the matter of ruggedness, simplicity and reliability, turbines of designs which have duly passed the diseases of infancy have made records which no other available prime mover is likely to surpass.

Directing attention more definitely to small units, and comparing the design of small turbines with that of larger ones, it will be found that, with reduction of size, difficulties increase rather than diminish. It is much more difficult, whatever the type of design, to embody favorable constants and dimensions in a small turbine than in a large one without sacrificing that degree of simplicity, or transcending that size and price, proper to the rating. Further, the relative magnitude and distribution of losses is inherently less favorable with smaller than with larger outputs. Added to these considerations is the fact that small turbines, more often than larger ones, have to be adapted to existing conditions rather than to be installed under conditions best adapted to them. It is necessary, then, to study the situation carefully, in order to produce a small turbine of thoroughly desirable characteristics.

Let us first determine what general type best lends itself to small units, then endeavor to further narrow our choice by comparing the available forms of the chosen type, and finally consider what mechanical arrangement will most advantageously embody the theoretical design determined upon.

We may primarily distinguish two types of turbine: Turbines in which the flow of steam is free, and those in which it is constrained. In the former, it is not necessary to hold the steam in its predetermined path through the buckets, since it follows this path of its own free agency, quite as the steam in an injector leaps across the gap between nozzles. In the constrained flow types, the steam is held to its proper path by appropriate parts of the turbine, and would, if permitted, escape from this path. The free-flow type is practically coincident with the "impulse"

method of operation, and the constrained flow with a "reaction" or "semi-reaction" method.

Segregation and determination of the losses of these two types will show that the size of unit plays an important part in their relative desirability.

With the constrained flow type, the clearance loss conforms to a law such that with decrease of size its percentage value and consequent detrimental effect on efficiency increases. The reason for this is obvious, — the mechanical clearance of this type cannot be reduced below a certain minimum amount dictated by mechanical considerations, and this amount necessarily becomes an increasing percentage of blade length as the size of unit and consequent blade length decrease. Since the leakage past blade ends is measured by this percentage, it follows a like law, as just stated. Also, the reduction of drum diameter resorted to for combating this tendency, coupled with the impracticability of surpassing a certain rotative speed, results in a reduction of peripheral velocity which enters as a square in the formula determining velocity-extraction by the moving buckets. These, together with some stage conditions later explained, are the primary considerations which render it impracticable to construct an efficient turbine of the Parsons type below a certain fairly large power, near the upper limit of what we have called small turbines.

Analysis of the losses proper to the impulse or free-flow type of turbine discloses no loss showing this very rapid increase in percentage with decrease in size. Rotation losses and shaft leakage losses suffer some percentage increase, but this can be kept within perfectly reasonable limits by intelligent choice of form of design, as explained in a later paragraph. There is, therefore, no inherent insuperable reason preventing the construction of very good small impulse turbines and, as we shall see, very satisfactory economies have been obtained.

The question of type having been answered, we have still to decide another very important general question, — the determination of the most advantageous form for this type to assume, — and this leads to a slight but necessary digression in which some general principles of design are hastily considered.

The fundamental condition which shapes problems of turbine design is the necessity of dealing with steam at very high velocities. It is well known that a steam jet impinging upon a moving impulse turbine wheel of usual design (see Fig. 2) will, corrections neglected, lose to that wheel an amount of

velocity-energy corresponding to loss of twice the wheel-bucket velocity, and hence, that the wheel, if it would extract all the velocity-energy from the steam, must travel with a rim speed equal to half the spouting velocity of the steam which drives it. Failure to extract all the velocity from the steam is somewhat analogous to failure to use all the available head of a water power, and has similar disastrous effect upon efficiency.

Considering the simplest case, suppose the entire contained energy of the boiler steam, dropping to exhaust pressure, be used in accelerating the steam itself in a single jet, — as the energy of a falling weight or water stream accelerates itself in a gravitational drop, — then the theoretical spouting velocities will be of the order of magnitude of those of modern projectiles, from 2 500 ft. to 4 000 ft. per second, according to boiler and exhaust conditions.

A single wheel of peripheral velocity at all approximating that called for by such jet velocities, and of reasonable diameter, will run at a rotative speed so high as to preclude direct connection to any machinery of sane design. Hence arises the fundamental steam turbine problem, to obtain a shaft speed low enough for a large class or classes of machinery, without in any considerable degree sacrificing the bucket conditions required for efficient operation.

The solution which would naturally first suggest itself is the use of gearing, as shown in Fig. 3. This was the arrangement first resorted to and with a very fair measure of success. The turbine with this arrangement is beautifully simple and, under suitable conditions, economical, The objections which attach center chiefly about the alignment and other details of the gearing, are of an obvious character and hardly require any particular discussion.

A second available expedient (shown diagrammatically in Fig. 4) consists in causing the high-velocity jet to be brought back by suitable guides against several successive wheels, or equivalent, losing at each " bounce " a velocity equal approximately to twice the wheel velocity. Obviously, if it rebounds from these successive wheels n times, the necessary wheel velocity required for extracting all the steam velocity will be only $\frac{1}{n}$th of that required with but one wheel. Here, then, we have a simple and very effective means of reducing shaft velocity, and one which elementary theory would indicate could be carried to almost any extent. Unfortunately, there is a loss at each " bounce," and it is hence not good practice to cause the

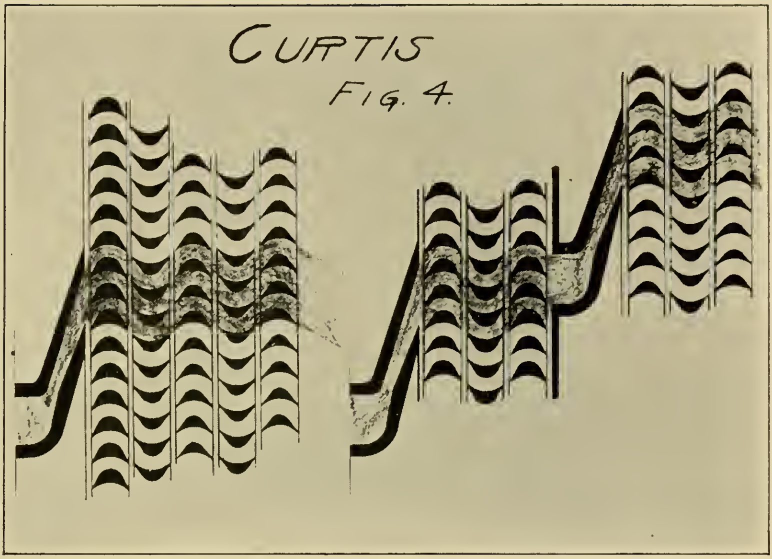


FIG. 4.

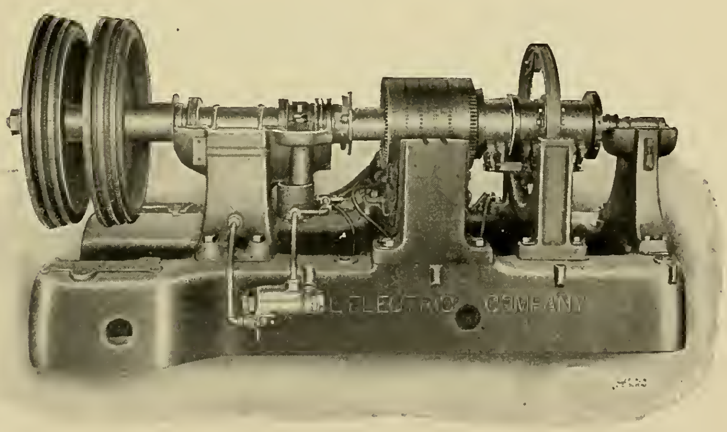


FIG. 5.

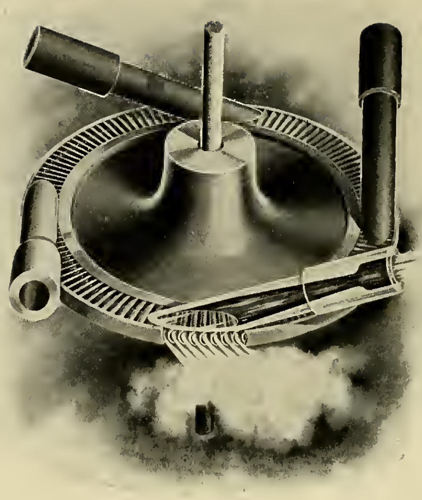


FIG. 2.

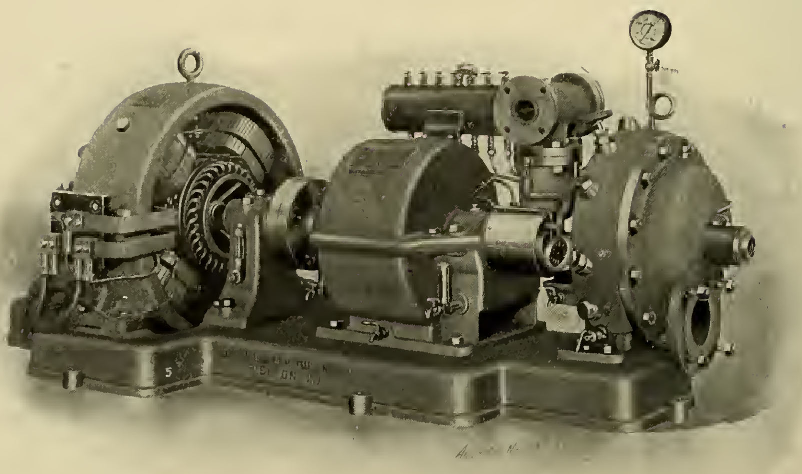


FIG. 3.

same jet to impinge upon successive wheels more than a very limited number of times, three being a number which should not ordinarily be exceeded. When this method is used, it is imperative that the steam path be short and simple, else the loss referred to will assume such proportions as to defeat the designer's object.

Still a third course (Fig. 4) develops the steam energy into velocity a step at a time. In this case the initial jet velocity is reduced and the corresponding wheel velocity becomes less. The steam after partial expansion and extraction of velocity is again expanded in another " stage " of an entirely similar character, developing a further installment of energy into velocity, and losing this velocity through impinging upon another moving wheel quite as before. This is a very efficient method, with the reservation that if too many equal stages are employed the early shell pressures become excessive and rotation loss and shaft leakage are thereby caused to assume abnormal values. This becomes a matter of particular importance in small designs.

It at once appears that the second and third methods are admirably adapted to be worked together in the same design.

Comparing the effectiveness — not efficiency — of these two methods of reducing shaft speed, we find the following:

With plurality of wheels per stage, the shaft speed is reduced in direct ratio as the number of wheels is increased.

With fractional expansion, involving several stages in series, the jet velocity and consequent wheel velocity and shaft speed do not decrease so rapidly as in direct ratio to the increase in number of stages, but only as the square root of that increase.

This last is for the reason that the energy of a jet is proportional to the square of its velocity; hence, if we make our expansion in, say, four stages, hence the energy of each jet one fourth of the total, its velocity will be one half that of a jet accomplishing the entire expansion. The corresponding effect upon wheel speed from use of four stages will thus be reduction, not to one fourth of former value, but only to one half; and, in general, n^2 stages must be employed to reduce wheel speed to $\frac{1}{n}$th of single-stage value. This principle, coupled with considerations of leakage and rotation losses, renders it highly inexpedient to attempt, in small turbines at least, a reduction of shaft speed solely by multiplicity of stages.

Summing up all our findings then we conclude that small turbines should be of the impulse type; that those for direct connection must have speed reduced by use of several wheels

in a stage, or by use of several stages, or by both; that but few wheels in a stage should be used and those with short, simple and accurately proportioned steam passages, and that the number of stages employed should be minimized.

The next problem which we shall consider is that of giving suitable embodiment to a design characterized by these features. The general mechanical problem, best arrangement of parts and mechanical details will be considered.

In addition to the usual problems, the turbine designer has to deal with a new group arising from high speed. These have to do chiefly with centrifugal stresses, balance, permanence of exact adjustments and of balance, bearings and suppression of noise. They assume different aspects with different detail designs, but all are susceptible of adequate and conservative solution.

Running balance is obtained by running the turbine rotor at high speed in a special support without constraint from bearings or other sources, or with constraint in only one plane. Means are provided for determining under these conditions whether bearing surfaces run accurately true or not, and, if they do not, for adding suitable weights until the unconstrained rotor runs absolutely true. This method is capable of great accuracy.

Permanence is assured by giving the rotating members a treatment producing a maximum permanent set of all yielding parts, such as armature insulation, and insuring that this "set" shall remain in the structure as it is assembled, Permanence of bearings requires such constants that film lubrication is at all times insured, whereupon bearing wear becomes absolutely inappreciable. Liability to wear or change at other points is combated by the use of liberal clearances and materials adapted to resist erosion or other destructive influences to which the individual part is exposed. The use of carbon in shaft packings obviates many troubles and marks an interesting departure from usual practice.

I believe the best general layout for very small turbines driving generators, pumps or blowers to be a two-bearing design with the turbine wheels overhung. (Fig. 5 shows the rotating element of such a design.) This is tolerant of bad foundation, since the two bearings are necessarily in line at all times. It also is conducive to a very compact, simple and accessible design.

Where the size is so great that, with a two-bearing layout, an unduly large shaft is required, an almost equally rugged and

flexible arrangement is achieved by use of three bearings for the combined unit, with a weight-supporting coupling carrying one end of one of the shafts. This will stand much abuse in the matter of foundation, is not sensitive to expansion or other disturbing influences and can be made the basis of an extremely compact and accessible arrangement. With this design the base plate should be very stiff, or else the coupling should be slightly flexible. (See Fig. 6.)

Regulation is by a centrifugal governor, with or without inertia feature. This governor controls a valve gear which in the smallest sizes is usually a plain throttle either with or without hand-operated auxiliary valves. In the larger sizes, the best practice is to use individual valves, serving one or more nozzles each. This gives a better efficiency than throttling, exactly as does a cut-off governor upon a reciprocating engine. The cut-off valve gear may be operated either by hydraulic, steam or mechanical means, and each method has some advantages.

Small steam turbines have found their principal field in the driving of electric generators. Another application which is assuming increasing importance is the operation of centrifugal pumps, and still a third that of centrifugal blowers. Marine work has thus far been mostly confined to sizes larger than 500 kw., but with the development of impulse type marine turbines, and with the possibility of gearing, there is no reason why this should remain true. Other applications are under consideration.

Electric generators driven by turbines — or turbo-generator units — have in larger sizes become very familiar. The smaller units have been less widely heralded, and on account of this fact and their inherent inconspicuity, they are much less well known.

I have not at hand statistics of the total number of small turbines now in use in America, but one company has sold at the date of this paper between twelve and thirteen hundred, which have been installed under a very wide range of conditions and in many industries. The percentage of troubles among even the earliest installations has been small, and all of those encountered have been due to minor mechanical features and not to difficulties inherent in turbine design. The record is one well justifying sanguine and optimistic predictions.

The economy of each design must be very carefully figured before the mechanical layout is begun. This is a process susceptible of considerable exactness, provided full general data

on nozzle and bucket efficiencies and on losses are available. Some charts on the former will prove of interest.

Losses are usually most conveniently given expression in a mathematical formula rather than by plotting. These formulæ are based upon mathematical analysis of empirically determined quantities and, as in other similar formulæ, it is not wise to extrapolate too far beyond actual data points. Efficiency computations must, of course, be checked, after completion of the unit, by careful tests taken under unexceptionable conditions.

The temptation to simplify mechanical problems by reducing speed below the economical points is always present with the turbine designer, but the fatal character of the objections to such a course is too obvious to require comment.

When due attention is given to both theoretical and practical requirements, eminently satisfactory efficiency can be, and is, obtained.

The electrical characteristics of turbo-generators require no small degree of special study, particularly in the case of commutating machines. It will not be possible to go further here than to make the general statement that generators of excellent mechanical and electrical characteristics are built, both in alternating current and direct current lines for turbine drive. Some of these generators, as for example, the train-lighting units in use on the tops of locomotives (Fig. 7), have to endure service of an exceptionally severe character and have stood the test for a period, and in a manner, which gives conclusive proof of the rugged character and permanence of the design.

Centrifugal pumps have in recent years gone through a process of refinement which has brought their efficiency and available pressure up to such a point as to bring them into direct competition with reciprocating pumps of high grade. Where such pumps require steam drive, the best available driver is in many cases the steam turbines, especially where high water-pressures are required. The new fire boat at New York is equipped with such pumps. The performance of these turbine-pump units is surprisingly good, not only from the standpoint of operation, but from that of efficiency.

Experiments of an elaborate and complete character conducted by one of the large turbine manufacturers indicated the possibility of considerably transcending customary pump speeds without impairment of efficiency. Very considerable developments are expected along the general line of turbine-pump work, and much good work is being devoted to this subdivision.

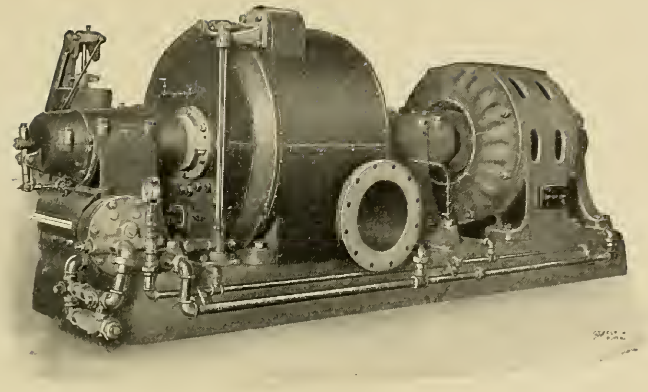


Fig. 6.

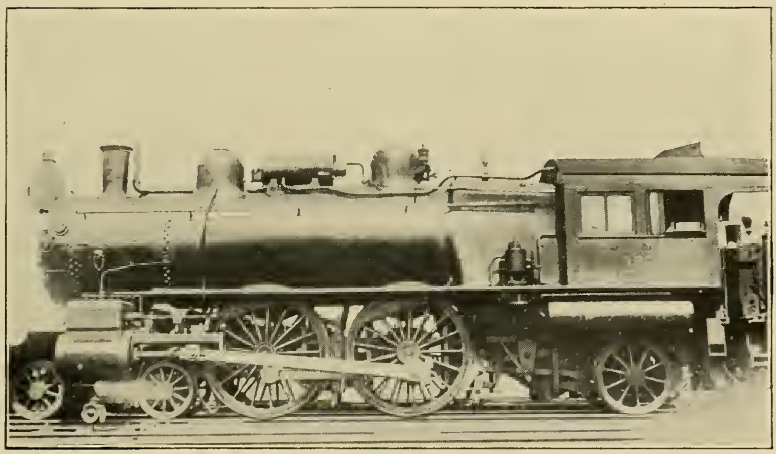


Fig. 7.

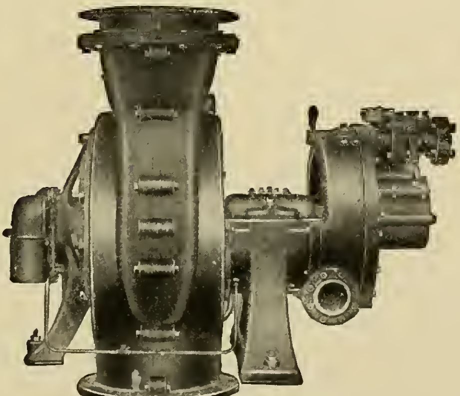


Fig. 8.

Centrifugal blowers may be developed and refined in a manner analogous to that which has characterized developments upon centrifugal pumps, and such development has been undertaken both here and in Europe. One large company in America has devoted a very considerable amount of money and work to this line, and has been rewarded by the accumulation of an adequate amount of data from which have been laid out and built a comprehensive line of high and moderate pressure centrifugal blowers. (Fig. 8.) The compactness and simplicity of such designs is admirable, and it is to be supposed that they will have a large degree of usefulness. The higher pressures are obtained by the use of a series of stages, running in present American practice up to a maximum of six.

Finally, the experimental period in the production of small turbines appears to be near its close and the standardization of types to be well begun. We may regard the best types of small turbine as representing stable and highly desirable forms, and as constituting a highly valuable accession to the available means of carrying on the world's work.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1910, for publication in a subsequent number of the JOURNAL.]

Association of Engineering Societies.

Vol. XLIV. JANUARY, 1910. No. 1.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, December 15, 1909. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President George B. Francis in the chair. One hundred and five members and visitors present.

As the record of the last meeting had been printed in the *Bulletin*, its reading was dispensed with and it was approved as printed.

Messrs. Howard K. Alden, Walter H. Allen, Elmer C. Houdlette, Charles R. Main and Charles R. Marsh were elected members of the Society, and Mr. Edward E. Savory, an associate.

The President announced the deaths of two members of the Society, Earle H. Gowing, who died November 24, 1909, and Laurence Bradford, who died December 6, 1909.

The President has appointed the following committees to prepare memoirs: On memoir of Mr. Gowing, Messrs. R. A. Hale and L. M. Bancroft, and on memoir of Mr. Bradford, Mr. Henry Manley.

The Secretary presented the report of the committee appointed to prepare memoir of William Parker, and on motion it was voted to accept the report and print it in the Journal of the Association of Engineering Societies.

On motion of Mr. Chase, the thanks of the Society were voted to the Coffin Valve Company for courtesies extended this afternoon on the occasion of the visit of members to the works of that company.

Mr. James W. Thomas, of New York, was then introduced and read the first paper of the evening, entitled, " An Account of the Tyng's Island Suspension Bridge, near Lowell, Mass." The paper was discussed by Mr. A. T. Safford, of the society, and Mr. Robert A. Marshall, of the office of Westinghouse, Church, Kerr & Co.

The second paper was read by Mr. J. R. Worcester, and was entitled, " The Bellows Falls Arch Bridge."

The third paper was by Mr. R. R. Evans, describing the old Chain Bridge at Newburyport and the new bridge now being erected on the site

of the old bridge. Prof. George F. Swain also contributed some additional information in relation to the new bridge.

The meeting closed with a brief recital of some interesting notes regarding the history of American bridges by the President.

All the papers were illustrated by lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., January 10, 1910. — The twenty-seventh annual meeting of the Civil Engineers' Society of St. Paul was held in the Secretary's room of the St. Paul Commercial Club in the Germania Life Building on Monday, January 10, 1910, at 6.30 p.m., with President H. J. Bernier in the chair. There were present twenty-eight members and four visitors.

The minutes of the previous meeting were read and approved.

It was moved, seconded and carried that Article 17 of the Constitution be and is hereby amended to read (effective January 1, 1910): "The regular annual dues for resident membership shall be, for members, five dollars ($5) per year; for non-resident members, two dollars ($2) per year."

The amended application of Mr. Paul K. Pulte was read; it was moved, seconded and carried that the Secretary cast the ballot of the Society electing Mr. Pulte to full membership as petitioned.

The election of officers for the year 1910 was then conducted and resulted as follows: J. D. DuShane, President; L. P. Wolff, Vice-President; D. F. Jürgensen, Secretary; Oscar Palmer, Treasurer; Henry A. Lyon, Librarian; A. R. Starkey, Representative on Board of Managers for the Association of Engineering Societies.

The reports of the officers for the year 1909 were read, accepted and ordered filed.

The retiring President, Mr. H. J. Bernier, hereupon surrendered the chair to the President-elect, Mr. J. D. DuShane.

The Examining Board for 1910 was appointed and consists of J. H. Armstrong, L. P. Wolff, A. R. Starkey.

The meeting thereupon adjourned to the banquet room to partake of the many good things that the committee had prepared, which were participated in by thirty-two members and five guests.

Mr. George W. Cooley gave a very lucid description of the highways as he found them in Europe, which he augmented with many photographs that he had taken.

Hon. A. O. Eberhart, Governor of the State of Minnesota, spoke at some length upon the important part the engineer takes in the upbuilding and development of the country, and of the great opportunities there are in this state to test the ability and resourcefulness of the engineer.

Mr. Andrew Rinker, City Engineer of Minneapolis, told what that city had done during 1909 in the way of municipal improvement. This

was responded to by Messrs. A. R. Starkey and C. L. Annan, of the City Engineer's office of St. Paul.

Messrs. Armstrong, Hogeland, Hollidge and Jürgensen responded to toasts, engaging the attention of the members until 11.30, when adjournment was taken by mutual consent.

D. F. JURGENSEN, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XLIV. FEBRUARY, 1910. NO. 2.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, October 6, 1909. — The 673d meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, October 6, 1909, President Wall presiding. There were present thirteen members. Minutes of the 670th, 671st and 672d meetings were read and approved. Minutes of the 465th, 466th and 467th meetings of the Executive Committee were read.

Following applications for membership were presented: Manly W. Cluxton, Cornelius M. Daily, Thomas N. Jacob, Edgar H. Lawrence, James D. Macpherson; for junior membership, Richard Gildehaus, Jr.

The Secretary then read a memorial prepared by Mr. Edward Flad to Mr. Julius W. Schaub, a former member of the Club, who died March 30, 1909.

The reading of the paper prepared by Mr. Wm. H. Bryan was postponed to a subsequent meeting. President Wall announced that the first joint meeting between the American Society of Mechanical Engineers and the Engineers' Club of St. Louis would be held on October 16 and that the program would consist of a paper by Prof. R. C. Carpenter, of Cornell University, on "The High-Pressure Fire Service Pumps of Manhattan Borough, City of New York."

The Entertainment Committee having provided refreshments, adjournment was taken to the adjoining rooms.

A. S. Langsdorf, *Secretary*.

St. Louis, November 3, 1909. — The 675th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, November 3, 1909, at 8.30 o'clock, President Wall presiding. There were present forty-one members and nineteen visitors. The minutes of the 674th meeting were read and approved. The minutes of the 469th meeting of the Executive Committee were read.

Mr. Philip Aylett was elected to membership.

Applications were read from the following: For membership, Walter Buehler, Henry Dickman.

The President announced that, according to the By-Laws, a nominating committee of five members must be elected at this meeting. The following nominations were made: Carl Gayler, W. E. Rolf, J. W. Skelly, W. H. Henby, H. C. Toensfeldt, A. P. Greensfelder. On motion, duly seconded, it was voted that nominations be closed. A ballot resulted as follows: Gayler, 36; Rolf, 28; Skelly, 26; Henby, 30; Toensfeldt, 33; Greensfelder, 37. The President thereupon declared the Nominating Committee to be as follows: A. P. Greensfelder, Carl Gayler, H. C. Toensfeldt, W. H. Hanby, W. C. Rolf.

Under the heading of miscellaneous business, Mr. W. H. Bryan announced a joint meeting of the Club and of the American Society of Mechanical Engineers for Saturday, November 13, and that a paper by Mr. E. R. Fish on " A Modern Boiler Shop " would be presented.

Mr. Arthur I. Jacobs then presented a most interesting paper on " The Coagulating Plant of the St. Louis Water Works." The text of the paper was liberally illustrated with lantern slides showing the details of construction of the coagulating house and of the machinery installed therein. The discussion following the reading of the paper was participated in by Messrs. Henby, Fish, Toensfeldt and Russell.

The meeting then adjourned to the adjoining rooms where the Entertainment Committee had provided refreshments.

A. S. Langsdorf, *Secretary.*

St. Louis, November 17, 1909. — The 676th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, November 17, 1909, at 8.30 o'clock, President Wall presiding. There were present twenty-three members and two visitors. The minutes of the 675th meeting were read and approved. The minutes of the 470th meeting of the Executive Committee were read.

The following were elected members: Walter Buehler, Harry Dickman.

The application of Mr. Leland Chivis for junior membership was read.

The Nominating Committee submitted the following report:

St. Louis, November 17, 1909.

The Engineers' Club of St. Louis:

Gentlemen: As your Nominating Committee, elected by you November 3, 1909, we have the honor to present the following nominations for officers of the Club during the coming year: President, M. L. Holman; Vice-President, J. D. Von Maur; Secretary and Librarian, A. S. Langsdorf; Treasurer, C. M. Talbert; Directors, J. W. Woermann, H. J. Pfeifer. Members of the Board of Managers, Association of Engineering Societies: John Hunter, Montgomery Schuyler, J. F. Bratney.

Respectfully submitted,

(Signed) H. C. Toensfeldt, *Chairman.*
W. H. Henby.
W. E. Rolfe.
A. P. Greensfelder.
Carl Gayler.

On motion of Mr. H. C. Toensfeldt, it was voted that the President appoint a special committee of three members to report on quarters at

the annual meeting. The President appointed the following committee: H. C. Toensfeldt, chairman; A. P. Greensfelder; W. H. Henby.

It was moved and seconded that a committee be appointed to secure for the Club library plans and specifications of the municipal free bridge, for the McKinley bridge and the Thebes bridge. Motion lost. The librarian was instructed to take steps to secure the plans mentioned in the above motion.

The paper of the evening on "The City Testing Laboratory" was then presented by Mr. Montgomery Schuyler. The history of the development of the present laboratory was sketched by Mr. Schuyler, its present activities described and suggestions made for its future development, Mr. Schuyler's idea being that the city testing laboratory should ultimately take over all testing work of whatsoever description in connection with the work of all city departments. The discussion following the paper was participated in by Messrs. Horner, Jacobs, H. C. Toensfeldt, Schuyler, Wall, Greensfelder, Hempelmann, Hoffman, Hendrich, Brenneke, Rolfe and Col. E. D. Meyer. The trend of the discussion was about equally divided between advocacy of, and opposition to, the scheme for future development of the city testing laboratory as set forth in the paper.

The President announced that the next meeting of the Club would be the annual meeting, at which meeting reports of officers and committees would be presented.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, December 1, 1909. — The 677th meeting of the Engineers' Club of St. Louis, the same being the annual meeting for the year 1909, was held at the Club rooms on Wednesday evening, December 1, at 8.30 o'clock, President Wall presiding. There were present forty-four members and seven visitors. The minutes of the 676th meeting were read and approved, and the minutes of the 471st meeting of the Executive Committee were read.

Mr. Leland Chivis was elected to junior membership.

The following applications were presented for membership: Roy J. Blackburn, George P. Fackt, Philip C. Grund, James A. Hooke.

The following reports, required by the Constitution, were submitted:

1. That of the Executive Committee, by Mr. E. E. Wall, chairman.
2. That of the Secretary-Librarian, by Mr. A. S. Langsdorf.
3. That of the Treasurer, by Mr. E. B. Fay. It was voted that the Executive Committee be authorized to have the Treasurer's records audited by a certified public accountant.
4. That of the Board of Managers of the Association of Engineering Societies, by Mr. O. W. Childs.
5. That of the Committee on Membership, by Mr. H. C. Toensfeldt.
6. That of the Entertainment Committee, by Mr. A. P. Greensfelder.

Mr. Greensfelder, chairman of the Committee on Quarters appointed at the last meeting and instructed to report at the annual meeting, stated that the committee had met several times and had held conferences with the officers of the Academy of Science for the purpose of discussing the steps to be taken at the expiration of the Club's lease at the end of the

present year. The committee had examined several alternative plans for future quarters, among them the possibility of maintaining headquarters downtown in connection with a buffet lunch-room, of securing some building centrally located for a club-house, or of renewing the present lease under proper safeguards. The committee had reached the conclusion that the latter alternative presented the best all-round features, the only objection being the noisy and poorly ventilated auditorium. The committee had asked Mr. C. A. Bulkeley, engineer of the Board of Education, to examine the building with a view to improving the auditorium in these respects, and, at the request of Mr. Greensfelder, Mr. Bulkeley then proceeded to outline several tentative plans that had suggested themselves to him. After further discussion it was voted to refer the entire matter of future quarters to the existing Committee on Quarters, which was given authority to close a contract with the Academy of Science, subject to the approval of the President of the Club, with the understanding that the committee might commit the Club to the payment of a maximum sum of $1000 for the carrying out of such improvements as may be deemed necessary, provided that this amount will be credited by the Academy of Science to the Engineers' Club as advance rental under the proposed lease.

The list of nominations for officers for the year 1910, presented by the Nominating Committee at the meeting of November 16, was then duly presented by order of the chair. There being no other nominations, as prescribed by the By-Laws, the list was ordered to ballot without change or addition.

The Secretary reported that he had taken steps to secure the plans and specifications of the Thebes bridge, the McKinley bridge and of the municipal free bridge, according to instructions voted at the last meeting, and stated that Mr. Ralph Modjeski had replied by sending copies of the report on the Thebes bridge and the printed specifications for the substructure and the superstructure of the McKinley bridge. The Secretary was instructed to make the proper acknowledgment to Mr. Modjeski for his kindness.

The Secretary read a letter from the Illinois Society of Engineers and Surveyors, announcing the annual meeting of that society at Cairo, Ill., January 26 to 28, and inviting members of the Club to attend.

On motion of Mr. Greensfelder it was voted that the Executive Committee be instructed to effect an arrangement with the Academy of Science and the Chemical Society for an exchange of notices of meetings with those societies and to proceed with the organization of a secretaries' club of the three organizations.

Mr. A. J. Widmer, of the Trussed Concrete Steel Company, then presented a large number of lantern slides showing examples of modern reinforced concrete construction.

The meeting then adjourned to the adjoining rooms, where the Entertainment Committee had provided light refreshments and cigars.

A. S. Langsdorf, *Secretary.*

St. Louis, December 15, 1909. — The annual dinner of the Engineers' Club of St. Louis (the 678th consecutive meeting) was held at the Mercantile Club on Wednesday evening, December 15, 1909, at 7.30 p.m. The total attendance was forty-eight, made up of forty-one

members and seven guests. Of the seven guests, two, Mr. Festus J. Wade and Dr. Wm. G. Moore, were the guests of the Club, the remaining five being guests of individual members.

After partaking of an excellent ménu, the President announced the result of the letter ballot for officers for the year 1910, as follows:

Total ballots cast, 136; ballots irregular, 6; net ballots cast, 130. The individual majorities were as follows:

M. L. Holman, for President, 128; J. D. Von Maur, for Vice-President, 129; A. S. Langsdorf, for Secretary-Librarian, 130; C. M. Talbert, for Treasurer, 129; J. W. Woermann and H. J. Pfeifer, for Directors, 129 each.

For Members of the Board of Managers, John Hunter, 130; Montgomery Schuyler, 129; J. F. Bratney, 129.

Mr. Wall then called on Mr. Holman, the incoming President, to act as toastmaster. The following toasts were responded to: "The General Education of the Engineer," Mr. E. E. Wall; "Reformation of the Currency System of the United States," Mr. Festus J. Wade; "The Engineer in Politics," Col. John A. Laird; "Engineers All," Dr. William G. Moore; "The Rising Generation," Mr. W. E. Rolfe.

The meeting adjourned at 11.30 P.M.

A. S. LANGSDORF, *Secretary.*

ST. LOUIS, JANUARY 5, 1910. — The 679th meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, January 5, 1910, at 8.30 o'clock, President Holman in the chair. The total attendance was 55. The minutes of the 677th and 678th meetings were read and approved. The minutes of the 472d and 473d meetings of the Executive Committee were read.

Mr. A. P. Greensfelder, chairman of the Committee on Quarters, read a letter from President Wm. Trelease, of the Academy of Science, concerning the contract and lease that had been entered into by the Engineers' Club with the Academy of Science for a period of five years beginning January 1, 1910. Under the terms of the lease, which had been approved by the President of the Club, the annual rental was fixed at $400 per annum, payable quarterly, and the Engineers' Club had agreed to expend the sum of $500 in renovating the rooms occupied by it and the corridor and stairway leading thereto and to install a ventilating system in the auditorium and sound-deadening window curtains.

The following committees for the year 1910 were announced:

Entertainment Committee: Wm. C. Zelle, Chairman; R. S. Colnon, Montgomery Schuyler, W. E. Rolfe, J. T. Garrett.

Membership Committee: E. S. Wall, Chairman; C. L. Hawkins, C. A. Bulkeley, W. S. Henry, Richard Morey.

President Holman presented to the meeting the question of the advisability of devoting one or more meetings of the Club for the discussion of the recommendations for the future organization of the Board of Public Improvements, as made by the present Board to the Board of Freeholders now drafting a new city charter. It was pointed out by the President that these recommendations were in substantial agreement with those made by the Club's representative when he appeared before

the Board of Freeholders at a recent date. On motion, duly seconded, it was voted that the Club undertake the discussion of the organization of the Board of Public Improvements with reference to the new charter.

The Secretary read a letter from Mr. C. M. Talbert, Assistant Engineer in the office of the President of the Board of Public Improvements, announcing the presentation to the Club library of a copy of the plans and specifications for the substructure, and a copy of the plans and specifications for the superstructure of the Municipal Bridge. A letter was also read from Mr. M. W. Cluxton announcing the donation to the library of three books containing the report on "Transportation Subways of the City of Chicago." On motion, duly seconded, it was unanimously voted to extend the thanks of the Club to Messrs. Talbert and Cluxton for their courtesy.

Mr. Von Maur mentioned the discussion at a recent meeting of the Executive Committee as to the advisability of establishing a question box to the end that members might submit, through the Secretary, questions that they might desire answered on any special topics for discussion. The Secretary announced that plans were under way for sending to all the members blank forms on which such questions or topics might be entered for filing.

The following gentlemen were elected to membership: James A. Hooke, Roy J. Blackburn, George P. Fackt, Philip C. Grund.

Applications for membership were presented from the following. Gomer L. Evans, Geo. A. Wettengel.

Mr. F. E. Washburn, Resident Engineer of the St. Louis Electric Bridge Company, then presented a most interesting address on the substructure of the McKinley bridge. The address covered the preliminary surveys, construction of the caissons, the sinking of the caissons and the building of the piers and the manufacture and driving of the concrete piles for the west approach. The address was copiously illustrated with excellent lantern slides. Lack of time prevented giving a description of the superstructure of the bridge now in course of erection, and this was reserved for the next meeting.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, January 19, 1910. — The 680th meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday, January 19, at 8.30 o'clock, President Holman presiding. In the absence of the Secretary, the President asked Mr. Horner to act as secretary *pro tem.* The total attendance was about fifty-five. The minutes of the 679th meeting were read and approved.

Mr. H. C. Toensfeldt, on behalf of the Committee on Quarters, asked for an expression from the Club as to the policy of accepting machinery or other fittings needed in the renovating of the quarters from non-members at reduced rates. It developed in the course of the discussion that certain non-members had offered to present to the Club some ventilating machinery. Moved by Mr. Schuyler that no offer of free machinery or of material at reduced rates be accepted. Motion lost.

The following gentlemen were elected to membership: George A. Wettengel, G. L. Evans.

An application for membership from Herman Spoehrer was read.

Mr. F. E. Washburn, Resident Engineer of the St. Louis Electric Bridge Company, then proceeded with the paper begun at the last meeting and took up "The Superstructure of the McKinley Bridge." He gave a short résumé of the first part of his paper and reproduced several of the views pertaining to the location and general character. He then took up in order the loading and specifications for the steel work and the paving of the bridge, and explained in detail the construction of the traveler and the erection of various spans. The paper was illustrated with many fine lantern slides, some of them giving excellent views of the ice conditions in the river at the time of the recent accident to the false work of the bridge.

Adjourned.

W. W. Horner, *Secretary pro tem.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., February 14, 1910. — The regular monthly meeting of the Civil Engineers' Society of St. Paul was held in the Society's quarters in the Old State Capitol Building on Monday evening, February 14, 1910, with President J. D. DuShane in the chair. There were present twenty-four members and thirty-two visitors. The minutes of the previous meeting were read and approved.

The committee, consisting of J. D. DuShane and Oscar Palmer, who were appointed to audit the Treasurer's books, reported that they had concluded their work and had found the books of account to be in good and accurate condition.

The petitions of Walter L. Van Ornum, Edmund S. Spencer and Adolph F. Meyer for full membership in the Society were read and upon motion duly made and seconded it was voted and carried that these applicants be and are hereby admitted to full membership as petitioned.

It was moved, seconded and carried that the names of John S. Potter, Walter P. Whitten and Gates A. Johnson, Jr., be and are hereby dropped from the membership rolls of the Society for non-payment of dues.

Upon the conclusion of the regular business of the Society, meeting adjourned to lecture room, where Mr. W. O. Washburn, Treasurer of the American Hoist and Derrick Company, entertained the members and their guests with a very complete and detailed description of the "*Railroad Ditcher*," which is manufactured by that company. The lecture was profusely illustrated by moving pictures, which showed this machine working under various conditions in different parts of the United States. Upon its conclusion Mr. Washburn was tendered a vote of thanks by the Society.

The meeting thereupon adjourned.

D. F. Jurgensen, *Secretary.*

Montana Society of Engineers.

BUTTE, MONT., JANUARY 6, 7, 8, 1910.

Thursday. — The work of the first day's session of the Society has usually been assigned to the membership residing some distance from the city where the annual meeting is held, that work consisting in making excuses for non-attendance, riding on delayed trains and preparing speeches in response to banquet toasts. This day's session differed in nowise from those of former years, except that the laborers were scarce and their reasons for absence more abundant and satisfying than ever before. Characteristic January weather, the convulsed condition of railway traffic and a long time between pay days were sufficient causes for absence on the part of anybody so afflicted.

Friday. — The forenoon was consumed in trips to various mines and plants in the vicinity. One party was taken to "The Hill," where the Speculator, Diamond and Bell surface plants received due attention as well as the Electric Power Station. Another party visited the Butte Reduction Works and the Butte Light and Power Plant, situated in the same locality. The time was too short to fully enjoy all the courtesies extended the visitors by the superintendents of the various works mentioned. In the afternoon a visit was made to the B. & M. Company's works and, under the care of Superintendent J. C. Adams, acting as official guide and interpreter, the engineers were taken through the Leonard Mine, shown "The Taft Drift," the Precipitation Works, the finest "Dry House" in the United States and the splendid surface equipment of those famous mines. In the evening, after enjoying the generous hospitality of the Silver Bow Club for a short season, the visiting members, accompanied by a few of the Butte contingent who knew the way, proceeded to one of Butte's most select and variegated theaters, where an hour's enjoyment was afforded. While the entertainment was beyond criticism, the only rivalry manifest was the enthusiasm of a few who recognized a good show when they saw one. An adjournment was had to a nearby resort where another entertainment, sometimes called a lunch, was had. Food, fun and fixtures were in variety and abundance, volume and volubility. The bunch withdrew in good order, though not defeated.

Saturday. — The annual business session of the Society was called to order in the State School of Mines Building at 10 A.M., President Charles H. Bowman in the chair. Thirty members present, more later on. Minutes of the last meeting approved as read. At this point the regular order of business was waived that Mr. H. N. Savage, of the United States Reclamation Service, might deliver a very interesting talk upon the work of his department in progress in Montana and other states, under his charge. His subject was illustrated by many fine pictures. The regular order of business being resumed, applications for membership in the Society were read as follows: Dennis Gregory Donahue, Frank Elbert Alexander, Francis Timothy Donahue, George R. Brown. On motion the applications were approved and the usual ballots ordered circulated. Charles H. Hills was elected to membership. The Secretary presented the ballots of the officers elected. Tellers Dunshee and Lincoln counted the same

and reported fifty-five ballots cast, all in the affirmative. President Bowman announced the following officers elected for the year 1910, to wit: President, Frank M. Smith; First Vice-President, Fred W. C. Whyte; Second Vice-President, Robert A. McArthur; Secretary and Librarian, Clinton H. Moore; Treasurer and Member of the Board of Managers of the Association of Engineering Societies, Samuel Barker, Jr.; Trustee for Three Years, John D. Pope. President Bowman presented President-elect Frank M. Smith, who assumed the duties of this office, expressing his appreciation of the honor conferred upon him. The annual reports of the Secretary and Treasurer were read and referred to the proper committee. The resignation of Mr. George Kuehner was read and accepted. Several letters from absent members expressive of good will and regrets for their absence were read by the Secretary. One in particular, from Mr. E. W. King, announced the serious illness of ex-President E. C. Kinney, and, on motion, Mr. Kinney was elected by a rising vote to honorary membership in the Society, and the Secretary was instructed to notify him of the fact by telegraph. On motion, Messrs. Goodale and Moore were authorized to telegraph Mr. Kinney the Society's regrets for his absence and words expressive of regard and esteem. On motion, the Secretary was ordered to publish a new and up-to-date "Year Book," making all essential changes and improvements. On motion, the Board of Trustees were instructed to look for other Society quarters, with power to act. The question of continuing membership in the Association of Engineering Societies and subscription to the JOURNAL OF THE ASSOCIATION brought out considerable discussion, which finally resulted in referring the whole matter to the Trustees and Treasurer Barker for investigation and a report at the next regular meeting. Change of date of annual meeting was a topic which elicited a lengthy discussion, and after thoroughly canvassing the situation the opinion seemed to prevail that any action was not wise at this session, though no definite steps were taken. Recess was taken till 2 P.M.

The afternoon session was called with President Smith in the chair. The first business of the session was the consideration and affirmative action on a motion as follows: That the President shall appoint a commission of three engineers from this Society, said commission to be instructed to formulate a plan for the construction of a state road in Montana; that $200 be appropriated from the funds of the Society to pay the necessary expenses of this commission; that the public press and commercial clubs shall be requested to aid in this improvement scheme; that this plan be presented to the governor of the state and his assistance secured if possible; that state legislation be sought along these lines; that said commission shall report back to the Society in October and at the next annual meeting the result of its labors. The address of the retiring President, Charles H. Bowman, was read and received close and well-deserved attention. A paper by Mr. Frank M. Smith was read by the author, giving an account of some machinery in use at the East Helena Smelter. Mr. Sydney R. Inch presented a very fine paper on the rebuilding of the Clark dam at Bonner, Mont. Stereopticon views added to the interest in this work. Mr. D. C. Bard gave a very graphic account of some geological developments in the mines at Radersburg, Mont. Mr. S. B. Robbins, of the Reclamation Service at Fort Shaw, Mont., gave

an excellent account of the progress of the work under his supervision, and the lantern views added to the success of the speaker's efforts. Mr. George M. Lewis presented a paper on "Common Sense Applied to Irrigation" at Manhattan, Mont., and, after a vote of thanks to all who had contributed to the success of the twenty-third annual meeting, the Society adjourned. A banquet was held in the evening.

CLINTON H. MOORE, *Secretary.*

BUTTE, MONT., FEBRUARY 12, 1910. — The February meeting of the Society was held on the above date with President Frank M. Smith presiding. The minutes of the annual meeting were read and approved. Will S. Hartman's application for junior membership in the Society was read and the regular ballot ordered. Messrs. Donahoe, Alexander, Brown and Donahoe were elected active members of the Society. Six members were suspended for four years' non-payment of dues. The Board of Trustees were given a month's further time to report on the matters referred to them at the last meeting.

The Secretary gave notice of the death of E. C. Kinney, honorary member of the Society, and the chair appointed the following committee to draft resolutions: Messrs. McArthur, Moore, C. M. Thorpe.

The chair appointed the following Committee on State Roads, as provided by resolution adopted at last annual meeting: Clinton H. Moore, Archer E. Wheeler, Charles W. Goodale. After some suggestions offered by the President and various members concerning the future of the Society, a motion to adjourn was adopted.

CLINTON H. MOORE, *Secretary.*

Technical Society of the Pacific Coast.

SAN FRANCISCO, FEBRUARY 4, 1910. — Regular meeting of the Technical Society of the Pacific Coast held at the Hotel Argonaut, where dinner was had before the regular business of the evening was taken up.

President Dickie called the meeting to order at 8 o'clock, whereupon the Secretary read the minutes of the last regular meeting, held November 26, 1909, which were approved upon motion.

The President stated that this was the annual meeting of the Society and that on this occasion the ballots for officers for the ensuing year, which had been sent to the Secretary, were to be opened by tellers and counted.

He thereupon appointed Mr. H. Homberger and Mr. M. L. Tower tellers to open and count the ballots, who reported that fifty-one votes had been cast in favor of the candidates as presented by the Nominating Committee. The President thereupon declared the following members duly elected officers of the Society for the year 1910: President, George W. Dickie; Vice-President, Loren E. Hunt; Secretary, Otto von Geldern; Treasurer, E. T. Schild; Directors, Lee S. Griswold, Hermann Kower, Bruce Lloyd, Frank P. Medina, G. Alexander Wright.

The President ordered the Secretary to inform these members of their unanimous election.

The President recommended that an effort be made to bring together all the scattered elements of the various engineering societies of San Francisco and to make an attempt to form some elastic unification by which these various societies, such as the American Society of Civil Engineers, of Mechanical Engineers, of Electrical Engineers, of Mining Engineers, and so on, may operate together without losing their identity and yet become capable of reaching a better field of labor at a smaller expense to the societies than at the present time.

This matter was taken under advisement and commented upon favorably by a number of members present. It was moved that a committee of three be appointed to confer with the American Society of Civil Engineers, that is, with its local association, and also with those gentlemen who were about to form a local society of members of the American Society of Mechanical Engineers, for the purpose of discussing some method of procedure towards this desirable end.

The President thereupon appointed Professors Marx and Wing and the Secretary a committee to confer with the Civil Engineers, and Messrs. Stut and Ransom a committee to confer with the Mechanical Engineers, of which committees the President will be a member.

The Secretary thereupon read the report of the Treasurer for the year 1909 as follows:

REPORT OF THE TREASURER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST FOR THE YEAR 1909.

January 10			
Cash in bank		$793.85	
Cash on hand		2.20	
			$796.05
Cash received during the year 1909 (items below)			719.25
			$1 515.30
Expended during the year 1909 (items below)		$645.72	
Cash on hand January 5, 1910		9.00	
Cash in bank January 1, 1910	$869.08		
Less two checks unpaid	8.50	860.58	
			$1 515.30
The receipts are as follows:			
Dues collected		$679.00	
Three admission fees		15.00	
Dinner receipts		22.75	
One JOURNAL and exchange on check		2.50	
			$719.25
The expenditures are as follows:			
Sundry expenses, stamps, envelopes, mailing, etc.		$46.07	
Printing and stationery		61.00	
Office work and collecting		25.50	
Salary of Secretary, eleven months		165.00	
Four assessments to Association of Engineering Societies		285.00	
Extra copies of JOURNAL		10.65	
Mechanics Institute, life members dues		6.00	
Funeral of Civil Engineer Calvin Brown		28.00	
Expenditures for dinner		18.50	
			$645.72

Respectfully submitted,

E. T. SCHILD, *Treasurer*.

SAN FRANCISCO, January 5, 1910.

This report was ordered received, accepted and spread in full upon the minutes.

The Secretary thereupon read a paper entitled "The Determination of the Ordinary High Water Plane on the Pacific Coast of the United States. A Discussion," by D. E. Hughes and Otto von Geldern, which was discussed by Col. W. H. Heuer, Morton L. Tower, C. E. Grunsky and others.

Mr. C. E. Grunsky thereupon addressed the members with some personal reminiscences of his past activities while a member of the Panama Canal Commission.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Louisiana Engineering Society.

New Orleans, January 8, 1910. — The annual meeting of the Society was called to order in the Hibernia Building at 8.30 p.m. by President Eastwood with twenty-five members and eleven guests present.

Upon motion, the reading of the minutes of the Society meeting of December 13 and those of the Board of Direction meeting of January 3 was dispensed with.

The annual report of the Board of Direction was read and upon motion received and referred to the new administration to take cognizance of recommendations contained therein and to take such action as may be necessary.

The annual reports of the Secretary, Treasurer and of the Chairman of the Information Bureau, and Auditing committee were read and ordered filed.

The annual report of the Library Committee was read, received and the recommendations contained therein referred to the incoming Library Committee.

Ballots for election of officers were then opened by Messrs. Wood, Brand and Miller, tellers appointed by the President, who announced the results as follows:

Number of ballots cast, 72, of which 6 were informal, leaving 66 ballots counted.

For President, W. B. Gregory, 65; J. W. Walker, 1. For Vice-President, John Riess, 65; W. J. Hardee, 1. For Secretary, L. C. Datz, 65; Thomas L. Willis, 1. For Treasurer, J. C. Haugh, 65; E. R. Barnes, 1. For Director to serve three years, Lyman C. Reed, 65; G. L. Haygood, 1.

President Eastwood congratulated the newly elected officers and appointed Mr. Lockett a committee of one to escort Professor Gregory to the chair, who, in a few well-chosen words, thanked the members for the honor they had conferred upon him.

The next in order was the address of the retiring President, J. T. Eastwood. Mr. W. B. Reed moved that, owing to the hour of the banquet having arrived, Mr. Eastwood be asked to deliver his address at the banquet instead of at the meeting, which motion, having the consent of Mr. Eastwood, was seconded and carried.

The meeting then adjourned in a body to the annual banquet at Gallatoire's, arranged by the Banquet Committee with W. B. Reed, chairman, and presided over by T. D. Miller, toastmaster. Some fifty-four men participated in the banquet. The following toasts were drunk:

"The Louisiana Engineering Society," J. T. Eastwood; "The Profession," Alfred F. Theard; "Future New Orleans," C. W. Wood and W. B. Reed; "The State," Sidney F. Lewis; "Inland Waterways," Col. Lansing H. Beach; "Our Guests," Dr. E. B. Craighead and R. E. Slade; "The National Engineering Societies," W. B. Gregory; "The Ladies," J. C. Haugh; "Our Dead," silent toast.

Besides the above, short remarks were made by O. K. Olsen and E. H. Bowser.

Mr. Reed, in the name of the Committee, presented Miss Wood with a souvenir as a slight token of appreciation for the excellent design on the menu card.

The banquet adjourned at 12.20 A.M.

L. C. DATZ, *Secretary.*

NEW ORLEANS, LA., January 8, 1910.

TO THE LOUISIANA ENGINEERING SOCIETY:

Gentlemen, — Your Board of Direction begs to report that during the year 1909 it has held twelve regular meetings and two special meetings for the transaction of the Society's business.

Attached are the reports of the Secretary-Treasurer, Auditing, Library and Bureau of Information committees, showing in detail the work done.

The financial report of the Secretary will show a balance of $171.68 with which to begin the new year.

The Treasurer's report shows receipts for the year, including the last year's balance, to be $2 036.09, and expenses $1 864.41.

The increase in the membership is small compared to last year, due somewhat to the small field to draw from.

The Future New Orleans Committee has done little recently, owing to the members of this committee having little time to devote to this important work.

Attempts were made to have an outing to Plaquemine Locks, but the committee lacked the enthusiastic support of the members necessary for its success, and the trip was called off.

The Advertising Committee placed two advertisements in the JOURNAL, which netted the Society a credit of $216.00 in our account with the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES

The Board wishes to call special attention to the good work done by the Library Committee, which has put the library in such shape as to be used to advantage; to the Advertising Committee, which was instrumental in adding materially to our treasury; and to the Bureau of Information Committee, which has been instrumental in placing so many men in positions of engineering work.

Acting upon advice of the last year's Board of Direction, a grade of honorary membership was created.

The Board of Direction would respectfully recommend that a committee be appointed to look into the social feature of the Society, and the advisability of securing larger and more comfortable quarters to take care of this feature, this committee to report back to the Society within a reasonable time the results of its labors.

Respectfully submitted,

THE BOARD OF DIRECTION,
JNO. T. EASTWOOD, *President*,
L. C. DATZ, *Secretary*.

NEW ORLEANS, January 3, 1910.

TO THE BOARD OF DIRECTION, LOUISIANA ENGINEERING SOCIETY:

Gentlemen, — As Secretary of the Society, I beg to submit the following report for the year 1909:

During the year there were ten regular meetings and one special meeting. Nine of these were held in the Hibernia Building and two at Tulane University.

The total attendance for the ten regular meetings, including guests, was two hundred and fifty-two, an average of twenty-five. The smallest attendance was thirteen, on September 13, and the largest was seventy-two, on December 13.

The membership roll for the year changed as follows:

	MEMBERS.			ASSO. MEM.		JUNIOR MEM.		
	Hon.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Total.
On roll January 6, 1909 . . .		100	22	4	0	7	2	135
Elected since		8	6	1		1		
Elected	1	−1						
Transferred		−5	5					
Transferred		2	−2					
Transferred			1			−1		
Resigned		−2	−1			−1		
Forfeited membership . . .		−1	−1					
Forfeited election		−3	−1					
Died	−1	−1						
	0	97	29	5	0	6	2	139
Net gain								4

Submitted separately is a financial report, which is attached to, and made part of, this report. It shows a balance on hand, January 1, 1910, of $171.68. Open accounts for dues, keys and badges amounted to $201.25, of which $3 have been cancelled, owing to death of members; $61 have been forfeited, and $3 have been collected, leaving $134.25 collectable.

The following technical exercises were held during the year:

January 9, address of retiring President, C. W. Wood; published. March 8, "Test of Gas Compressor," paper by W. B. Gregory; published. April 12, "Intake of New Water-Works System," J. W. Armstrong. May 10, "Heat, Its Use and Distribution," L. C. Reed; published. June 6, "Recent Work on Chalmette Monument," Alf. F. Theard; published. October 10, "Interurban Railway Development in the South," J. W.

Billingsley. December 13, "The Growth of Cast Iron Produced by Repeated Heating," Prof. H. F. Rugan.

The Society, acting on recommendation of last year's Board of Direction, created an Honorary Membership by amending Articles II and VII of the Constitution, and ordered the cataloguing of the library.

The Society elected John M. Ordway as Honorary Member, who died one month after his election.

The Society finally endorsed the McKinley Bill providing for the establishment of engineering experimental stations in land grant colleges.

The Society added the American Society Mechanical Engineers on its exchange of house and library privileges, making nineteen in all.

There were five ballots for new members taken during the year, with an average of sixty ballots.

The Secretary takes this opportunity to thank the individual members of the Board of Direction for the hearty coöperation in the work connected with his office, and to Mr. T. D. Miller for the courtesies extended in placing an addressograph at the service of the Society.

Respectfully,

L. C. DATZ, *Secretary.*

TREASURER'S REPORT.

NEW ORLEANS, January 4, 1910.

Balance on hand, January 5, 1909	$ 193.22
Received from Secretary, as per attached list	1 842.87
	$2 036.09
Paid out in vouchers 1 to 87 inclusive, as per attached list .	1 864.41
Balance on hand, January 4, 1910	$171.68

JAS. C. HAUGH, *Treasurer.*

NEW ORLEANS, January 6, 1910.

TO THE BOARD OF DIRECTION, LOUISIANA ENGINEERING SOCIETY.

Gentlemen, — We have examined the reports of the Secretary and Treasurer, and have gone over their accounts and find them correct and in proper shape.

THE AUDITING COMMITTEE,
W. B. GREGORY.
J. W. ARMSTRONG.
MARCEL GARSAUD, *Chairman.*

NEW ORLEANS, December 29, 1909.

BOARD OF DIRECTION, LOUISIANA ENGINEERING SOCIETY.

Gentlemen, — I herewith beg to hand you report of twenty-seven positions obtained through our efforts. The attached list is for permanent positions only, and in addition to same we have placed between forty and fifty engineers and draftsmen in temporary positions during the past year.

Yours very truly, HERMAN KOKOSKY,
Chairman Information Bureau.

Report of Library Committee.

The Library Committee submits the following report for work done during the year 1909:

All the books in the library have been accessioned, and a card catalogue made of them. A good many of the books have been cross-indexed under more than one subject. Placed in the same case with cards of our own library are those of all books on engineering subjects in the Howard, Tulane University, and the public libraries. Books from other libraries are indexed on cards of different colors, and no books in our library are listed with the Howard Library, and no books listed with the Howard and our libraries are listed with the Public Library, and no books listed with the three libraries just named are included with the Tulane Library list. By doing this, duplicate cards are omitted from our case.

The total volumes indexed are as follows:

	Volumes.	Cards.	Color.
Louisiana Engineering Society	910	1 050	White
Howard	306	400	Yellow
Public	251	300	Salmon
Tulane	238	300	Blue
Total	1 705	2 050	

As a matter of record, the committee gives separately a list of periodicals, transactions on file in our rooms and various trade publications and reports sent to the Society.

The Society has donated one copy of the Journal of the Association of Engineering Societies to each of the following libraries: Howard, Public and Tulane, and it is indebted to Mr. A. Godbold for the *Engineering Index* for 1906; to Mr. E. B. McKinney for miscellaneous issues of the American Institute of Electrical Engineers; to the Universities of Illinois and Wisconsin for complete files of their bulletins, the latter going to considerable trouble to procure numbers which were out of print.

LIBRARY EXPENSES.

Periodical subscriptions	$34.50
Binding sixty-four books	64.00
Cataloguing and indexing	74.75
Material for same	16.70
Magazine rack	9.00
Books, *Engineering Index*	14.00
Back issues of *Engineering Magazine*	2.75
Total	$215.70

RECEIPTS.

Sale of old engineering magazines	$5.00
Balance on hand from periodical appropriation	1.00
Total	$6.00

It was the intention of the committee to purchase a number of new books, but the expense of binding old volumes and of indexing left nothing for that purpose.

On retiring, the committee would recommend to the Society and to its successor the necessity of adding to our list of periodicals and keeping abreast of the times by purchasing new text-books as they appear.

Respectfully submitted,

J. W. Armstrong, *Chairman*,
R. T. Burnwell,
L. A. Godbold,

Committee.

Association of Engineering Societies.

Vol. XLIV. **MARCH, 1910.** No. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, February 2, 1910. — The 681st meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, February 2, 1910, at 8.30 o'clock, President Holman presiding. There were present fifty-one members and seven visitors. The minutes of the 680th meeting were read and approved.

The Secretary read a letter from Mr. Halsey C. Ives offering as a donation to the Club a portrait of Mr. Andrews painted by Mr. Conant and asked whether the Club cared to accept the portrait. Upon motion of Mr. Pitzman seconded by Mr. Pfeifer, it was voted that the picture be accepted. Moved by Mr. Colnon, and seconded, that the President appoint a competent member to inspect and receive the picture. Motion carried. The President thereupon named Mr. R. S. Colnon.

The Secretary read a set of resolutions drawn by Col. J. A. Ockerson dealing with the subject of the status of civilian engineers in the Engineering Corps of the United States Army. In substance the resolutions were to the effect that the Club take steps to interest Congress and other clubs, members of the Association of Engineering Societies, in enacting legislation for the purpose of securing to qualified engineers equal standing with graduates of the United States Military Academy. A motion by Mr. Langsdorf to adopt the resolutions was amended by Mr. Flad to read that the resolutions be referred to the Executive Committee for such modification as may be deemed necessary. The amended motion was again amended to the effect that the resolutions be referred to a special committee of five to be appointed by the Chair, the committee to have power to accept the resolutions as presented, to make such changes as might be deemed necessary, or to refer the whole matter back to the Club. The motion as finally amended was carried. The President later named the following committee: Edward Flad, chairman; B. H. Colby, W. H. Bryan, C. M. Talbert, H. J. Pfeifer.

On motion of Mr. Langsdorf it was voted that the thanks of the Club be tendered to Mr. H. A. Wheeler for the donation to the Library of two volumes of proceedings of the Massachusetts State Board of Health

Mr. Herman Spoehrer was elected to membership.

Applications for membership were read from the following gentlemen: John Anderson, F. G. Jonah.

The Secretary read a letter from Mr. H. L. Eaton, a visiting member of the American Institute of Mining Engineers, asking that the use of the Club Library be granted to him during the period of his visit. Upon motion of Mr. Von Maur, duly seconded, it was voted that the courtesies of the Club be extended to Mr. Eaton during his stay in the city and that it be the regular policy of the Club to extend its courtesies to visiting non-resident members of each of the four national engineering societies.

The program of the evening as arranged by the Executive Committee consisted of a discussion of the proposed amendments to the Charter as affecting the organization and duties of the Board of Public Improvements. The basis of the discussion was a detailed communication dated November 23, 1909, from the present Board of Public Improvements to the Board of Freeholders.

The discussion was opened by Mr. Pitzman, a member of the Club and also of the Board of Freeholders, who stated that it was the policy of the Board of Freeholders in drawing up a new charter to make the predominant officers in the conduct of city business, engineers. He suggested that the proposed amendments be read and discussed section by section. Mr. Holman explained that in general the new plan contemplated a Board of Public Improvements subordinate in rank to the Mayor and the Municipal Assembly and which in turn controlled parallel organizations, one an engineering department for the planning of new work, the other an operating department for carrying on of routine affairs, and that each of the latter in turn had supervision over groups of special departments capable of further subdivision as occasion might require.

Discussion of Sections 1 to 10.

Mr. Flad said that the issue seemed to be whether the Board should be an independent board or subject to removal by the Mayor. He personally favored an independent board.

Mr. Russell objected to one-man power.

Mr. Von Maur suggested that removal of any member of Board by the Mayor should be subject to approval by remaining members of the Board.

Mr. Pfeifer favored centralized power of removal in hands of one man.

Mr. Schuyler suggested organization of a commission to act instead of the Mayor in cases of removal.

Mr. Flad objected to the requirement that the Mayor name the appointees to the Board the day after taking office.

Mr. Pitzman agreed with Mr. Flad on this point and thought that a period of from six to twelve months would be a more suitable interval.

Mr. Garrett suggested that the removal of Board members by the Mayor be subject to the approval of the Council.

Mr. Skelley pointed out that it was proposed to elect the Mayor in November and to induct him into office in January and thought that the interval of two months would be ample for the selection of appointees to the Board.

Mr. Emmanuel and Mr. Woermann asked whether the merit system had been considered for appointments to the Board or subordinate offices.

Mr. Pitzman replied that no action had thus far been taken with

respect to the merit system. It was thought that members of the Board would be the best judges of the qualifications of employees.

Mr. Flad stated his belief that it was very important to incorporate in the charter some form of civil service for the selection of employees.

Section 34.

Mr. Schuyler asked whether the Board of Freeholders had studied the question of the Commission form of municipal government.

Mr. Pitzman replied that the Board had studied the matter and had found that in some places the system worked well, in others not.

Mr. Holman pointed out that it was proposed to relieve members of the Board of all departmental affairs for the reason that the increasing amount of city business required all their time for Board work.

Mr. Russell suggested that there be no residential requirements for engineers.

Sections 39 and Following.

Mr. Pitzman said that it was his personal preference to establish a separate park commission instead of a single Park Commissioner to take charge of all parks, public grounds, playgrounds, etc., and to employ a qualified landscape gardener with a provision that all such work as related to the construction of roads, bridges, etc., be put in charge of the Street Commissioner.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, January 26, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.

President George B. Francis in the chair; eighty members and visitors present.

The record of the last meeting, as printed in the *Bulletin*, was approved.

On motion the President was requested to appoint a committee of three to report to this meeting the names of five members to serve as a committee to nominate officers. The following were appointed as the committee: George A. Kimball, F. A. Barbour and R. A. Hale. This committee reported later in the meeting the following names and, by vote of the Society, they were chosen as the nominating committee: Joseph R. Worcester, F. H. Carter, Charles R. Felton, Richard K. Hale and Charles R. Gow.

The Secretary announced the death of John H. Emigh, a member of the Society, which occurred January 6, 1910, and on motion the President was requested to appoint a committee to prepare a memoir.

The Secretary presented the report of the committee appointed to prepare a memoir of Earle H. Gowing, and on motion, it was voted to accept the report and print it in the Journal of the Association of Engineering Societies.

The President reported for the Board of Government a recommenda-

tion that the Annual Meeting this year be similar in form to that of a year ago. On motion of Mr. E. P. Adams, it was voted that the Board of Government be requested to arrange for the Annual Meeting and other functions similar to those held last year.

On motion of Mr. R. K. Hale, the following votes were passed:

That the thanks of the Society be extended to Harry P. Nawn, president of the Hugh Nawn Contracting Company, for courtesies shown this afternoon on the occasion of the visit of the Society to the work now in progress on the Cambridge Main Street Subway.

That the thanks of the Society be extended to the officials of the Boston Elevated Railway Company for courtesies shown this afternoon on the occasion of the visit of the Society to the work now in progress on the Cambridge Main Street Subway.

The literary exercises of the evening consisted of a very interesting talk by Mr. William L. Church, entitled " Hydraulic Power Development with special reference to Ambursen Dam Construction."

The talk was illustrated by a large number of lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, February 16, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 p.m. o'clock. President George B. Francis in the chair; 145 members and visitors present, including ladies.

The record of the January meeting, as printed in the *Bulletin*, was approved.

Messrs. William A. Cobb, Samuel P. Coffin, William J. Fielding, Clarence B. Humphrey and Leroy D. Peavey were elected members and Mr. Theodore L. Keppler an associate of the Society.

On motion of Professor Breed, the thanks of the Society were voted, to the American Waltham Watch Company; to Mr. J. W. Burkes, the General Superintendent, and C. J. Olney, Jr., the Purchasing Agent, of that company and to the Boston & Maine Railroad Company, for courtesies extended to members on the occasion of the visit to the factory of the Watch Company, at Waltham.

Professor Sanborn brought to the attention of the Society the desirability of making arrangements with the officials of the Boston Public Library by which the engineering books in the Library will be more accessible.

Mr. Herman K. Higgins then gave an illustrated talk entitled, " Progress at Panama."

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

The last meeting of the Sanitary Section was held at the Boston City Club on Wednesday evening, January 12, at 7.30 o'clock.

Mr. William Gavin Taylor of the Passaic Valley Commission gave an admirable talk on the theory and design of trickling sewage filters, illustrated with lantern slides. In the course of his remarks Mr. Taylor

described many types of sewage sprinklers and discussed quite fully the different types of under-drainage systems of trickling filters.

The other speaker of the evening was Mr. O. M. Weand, the builder of the sewage disposal plant at Reading, Pa. Mr. Weand described in detail the construction and operation of the plant and particularly that of the rotary sewage screen, which has effected great economy in the operation of the sewage sprinklers by removing nearly all of the suspended matter. His talk was also illustrated.

About fifty members and guests were present.

Robert Spurr Weston, *Clerk.*

The annual meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Boston City Club on March 2, at 7.30 o'clock.

Mr. G. Frank Kemp was elected a member of the Section. Reports of the Executive Committee and the committees on "Rainfall and Run-Off," "Collection and Tabulation of Sewerage Statistics" and "Uniform Specifications for Vitrified Sewer Pipe" were read and placed on file. The three special committees of the Section were continued. The following officers were elected for the coming year:

Chairman — Robert Spurr Weston.
Vice Chairman — Leonard P. Kinnicutt.
Clerk — Harold K. Barrows.
Additional members of the Executive Committee — Frank A. Barbour, Stephen DeM. Gage, John L. Howard.

Dr. George A. Soper, chairman of the Metropolitan Sewerage Commission, New York City, gave an interesting lecture on the subject of air contamination, which was illustrated with lantern slides and discussed by several members. Forty-three members and guests were present.

Robert Spurr Weston, *Clerk.*

Boston, March 16, 1910. — The annual meeting of the Boston Society of Civil Engineers was held at the Boston City Club, 9 Beacon Street, at 12 o'clock m., President George B. Francis in the chair.

The record of the last regular meeting, as printed in the March *Bulletin*, was approved.

The President appointed as tellers to canvass the ballots for officers to be elected at this meeting, Messrs. N. S. Brock and H. K. Higgins.

Messrs. T. Morris Brown, Frederic Kent Lawrence, Edward Guild Lee, Charles Bernard McNally, Henry Walter Routenburg, Ralph Edmund Smith, Lewis P. Steele, Jr., Reynold Henry Sutherland and Edward Wright, Jr., were elected members of the Society.

The Secretary read the annual report of the Board of Government and, on motion, it was accepted and placed on file.

The Secretary also read his annual report and, on motion, it was accepted and placed on file.

The Treasurer read his annual report and, on motion, it was accepted and placed on file.

Mr. Carter, for the Committee on Excursions, presented its annual report, which was accepted and placed on file.

The Librarian read the annual report of the Committee on the Library and, on motion, it was accepted and placed on file.

Mr. FitzGerald presented and read the joint report of the Board of Government and the Committee on Permanent Quarters. The report was accepted and placed on file.

Mr. Cowles presented a report of the Special Committee on Clubhouse, appointed by the Board of Government. The report was accepted and placed on file.

The Secretary read a communication from the Engineers' Club of St. Louis, enclosing resolutions adopted by that Club concerning pending legislation before Congress in relation to a Department of Public Works, and requesting this Society to consider the resolutions with a view to adoption of similar action. On motion of Mr. Sherman it was voted to refer the communication to the Board of Government, to report in print in the next *Bulletin* such action as it deemed best.

On motion duly made and seconded it was voted to refer to the Board of Government, with full powers, the question of appointing the special committees of the Society and the selection of the members thereof.

It was voted to appropriate the sum of $75 for the purchase of new reference and text books during the coming year.

On motion it was voted to request the Board of Government to appoint a committee on the revision of the By-Laws of the Society.

President Francis then delivered the following address:

The reports of the Board of Government and the several committees have informed the members of the current affairs of the Society.

There is not much to be said at this time which these reports do not disclose; nevertheless, there are a few matters which I will touch upon, which have been impressed upon me during my term of office.

I believe that it would be well for the Society to issue, at cost, engraved certificates of membership to such members as desire them; that the Constitution should embrace a provision for the compounding of annual dues; that a sum of money, say $50 or $100, should be set aside each year as a prize for the best descriptive paper furnished, in the hope that this incentive will improve and increase the papers submitted.

I believe that the annually increasing expense of the Society will eventually require an increase in the annual dues paid by members, and that the Constitution should soon be revised, providing for such increase to all present members, and for one or more classifications of members, particularly juniors, who might be admitted at the present rate of dues for members.

It might also be well to make the qualifications for membership substantially the same as is required for the national society, so that this Society may have equal rank in this respect to any other.

The increased income from dues to be applied eventually to a larger compensation of the Secretary, perhaps ultimately to a point where the whole time of this officer can be given to the requirements of the Society and, finally, to the publication of the transactions of the Society by itself.

I believe that a revision of the Constitution in these particulars will tend to increase the membership and the dignified standing of the Society, and these matters are suggested for the future consideration of the Society.

A year ago my predecessor in office, in his address at the annual meeting, called attention to a number of matters which he thought were

open to improvement and which might be summed up generally as follows:

That there appeared to be a disease in the Society that is "sometimes wrongly called 'dry rot'"; that there appeared to be a lack of sympathy between the older and younger members, also a "restiveness" on the part of the younger members; that the meetings were not made as attractive as they might be; that it is desirable to print the papers in advance of presentation; that there was not as much free offering of papers as desirable; that the method of selecting officers was open to criticism.

Believing that these criticisms were stated with a view to the good of the Society, and knowing that they resulted from a year's experience in the office of President, it became a natural duty of the new Board of Government to profit by this experience and these observations; consequently, much effort has been made to apply medicine to the disease, establish sympathy between members, secure more attractive meetings, print some papers in advance and lead the members on toward the free offering of papers.

A year's application of available medicine to the disease at least puts the Society in the position of a real patient I once knew who wrote his physician saying, "I have now taken your medicine for several months and I find myself no worse."

Personally, I think the Society is far from going out of business on account of any chronic disease. I have not observed any "lack" of sympathy between the older and the younger members. Whenever I have called on any member of the Society for aid in any direction, there has been a most cheerful assistance given. In the matter of nominating three candidates for each office, instead of one candidate as is done in other societies, I am inclined to believe that there is merit in giving the membership a choice, rather than having the nomination equivalent to an election.

There is restiveness among the members of the national society on this account. At any rate, this is not to my mind a very serious defect.

Perhaps I am not the best judge of whether the meetings during the past year have or have not been as attractive as we would like, but they have proved interesting to me and I have enjoyed being present even at considerable discomfort to myself in making the effort.

There has been no trouble in finding papers for all the time available and I feel under deep obligation to those non-resident members who have supported, so freely, my request for effort in this line. As a matter of fact, each member, resident or non-resident, who was appealed to has produced results, and there are papers yet to come from such appeals for which no time, at either formal or informal meetings, has yet been found.

As to the quality of the papers, it can perhaps be best answered by the statement that the attendance during the past year has been up to or above the general average and there has been considerable free discussion.

I believe that the Society is alive and progressive and am induced to make these remarks to counteract the effect of the remarks of my predecessor who, although having the good of the Society at heart and being sincere in his endeavor to improve it, drew a picture that was depressing.

His remarks have, nevertheless, resulted in an endeavor on my part to bring about, as far as my ability permitted, a point of turning toward a third brilliant chapter in the history of the Society, and in that respect his remarks may prove valuable.

Before completing my remarks I desire to offer strong encouragement to the Joint Committee on club house matters, which I hope will serve to increase their faith in a successful issue of any reasonable plan which they may finally adopt; and for this purpose, I propose to read an extract from the last annual report of the Secretary of the American Society of Civil Engineers found in the report of the annual meeting:

"It might be interesting to call attention to the facts shown in the

balance sheet. According to it, if we omit the items of furniture, publications on hand, and value of the library (on which it might be difficult to realize), the actual assets of the Society, which could be turned into cash, on December 31, 1909, were $354 619.51.

"In a circular issued by the Board of Direction, May 25, 1895, at the time the building of a new house was contemplated, the available assets at that time were stated to be $64 500.

"The present estimated value of the Society's property is believed to be extremely conservative, but nevertheless it appears that in less than fifteen years the assets of the Society have been increased by about $290 000."

I desire to thank those members of the Board of Government and committees who have supported me in all our endeavors to make the year a success.

On motion of Mr. FitzGerald the Board of Government were requested to consider the advisability of offering a prize for the best paper presented to the Society each year.

On motion of Mr. Hodgdon, it was voted to print in the next *Bulletin* the suggestions offered by the President in his address and that they be taken up for consideration at the April meeting. Later, this vote was reconsidered and the meeting took up the consideration of the several suggestions contained in the President's address.

On motion duly made and seconded, the Secretary was instructed to have a proper certificate of membership prepared.

It was also voted to refer to the Committee on Revision of By-Laws, when appointed, the question of compounding annual dues.

The suggestions in the address, relating to an increase in the annual dues and for one or more additional classes of members, was discussed, and finally referred to the Board of Government for a report.

Mr. Johnson presented the following resolution which, after a discussion, was adopted unanimously: *Resolved:* That it is the sense of this meeting that as soon as the finances of the Society shall warrant it, the Boston Society of Civil Engineers should publish an independent journal.

The tellers of election submitted their report, giving the result of the letter ballot. In accordance with the report, the President announced that the following officers had been elected:

President — Henry F. Bryant.
Vice-President (for two years) — James W. Rollins, Jr.
Secretary — S. Everett Tinkham.
Treasurer — Charles W. Sherman.
Librarian — Frederic I. Winslow.
Director (for two years) — Frank A. Barbour.

Before declaring a recess to partake of the annual dinner, the President introduced the president-elect, Mr. Bryant, who briefly thanked the members for the honor they had conferred upon him, and expressed his appreciation of the election.

The members then adjourned to the auditorium of the Club House, where members and guests to the number of 158 sat down to the twenty-eighth annual dinner.

After the dinner President Francis again called the meeting to order and introduced Past President John R. Freeman, who gave a very interesting account of the Los Angeles Aqueduct which was profusely illustrated with lantern slides.

Before adjourning the meeting the President thanked the members for the support and assistance which they had given him during the year and the president-elect took the occasion to express the appreciation, not only of the Board of Government, but of all the members, of the faithful and enthusiastic service rendered by the President the past year, which, because of his residence so far from Boston, must have called for much personal sacrifice.

In the evening a smoker was held in the auditorium of the Boston City Club, at which the attendance was over two hundred and seventy-five. The smoker was of the same informal character as last year; light refreshments were served and excellent music was furnished by an orchestra; but the most enjoyable feature was the singing of some old-time songs and many new ones, the words of which were written by members of the Society for the occasion. The opinion was unanimous that this sixty-second anniversary of the founding of the Society was even better than any which had preceded it.

S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1909–10.

Boston, Mass., March 16, 1910.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the Constitution, the Board of Government submits its report for the year ending March 16, 1910.

At the last annual meeting the total membership of the Society was 678, of whom 664 were members of the Society, 3 honorary members, 11 associates and 19 were members of the Sanitary Section only.

During the year the Society has lost a total of 29 members; 13 by resignation, 10 by forfeiture for non-payment of dues, and 6 have died.

There has been added to the Society during the year a total of 74 members of all grades; 66 have been elected and 6 reinstated to membership in the Society, and 2 have been elected to membership in the Sanitary Section. Three others have been elected, but have not at this date completed their membership.

The present membership of the Society consists of 3 honorary members, 15 associates and 705 members, of whom 18 are members of the Sanitary Section only; making the total membership 723, a net gain of 45.

The record of the deaths during the year is:

Lewis Frederick Rice, a past president of the Society, died April 12, 1909.

Edwin W. Ellis died August 3, 1909.
William Parker died September 30, 1909.
Earle H. Gowing died November 24, 1909.
Laurence Bradford died December 6, 1909.
John H. Emigh died January 6, 1910.

Ten regular, one special and four informal meetings of the Society have been held during the year. The average attendance at the regular and special meetings was 138, the largest being 700 and the smallest 45. The average attendance the year previous was 82, showing an increase of about 70 per cent. for this year.

The following papers have been read at the meetings:

March 17, 1909. — George B. Francis, "Railroad Terminal Improvements at Providence, R. I." (Illustrated.)

April 21, 1909. — E. R. B. Allardice, " Reforestation of the Marginal Lands of the Wachusett Reservoir of the Metropolitan Water Works." (Illustrated.)

May 5, 1909. — (Special) Frederic P. Stearns and Allen Hazen, " Description of Panama Canal and Work thereon Accomplished to Date." (Illustrated.)

May 19, 1909. — E. P. Dawley, " Railroad Tunnel Recently Built at Providence, R. I., for New York, New Haven & Hartford Railroad." (Illustrated.)

June 16, 1909. — Henry F. Bryant, " A High Head Hydro-Electric Development in Vermont." (Illustrated.)

September 15, 1909. — J. W. Rollins, Jr., " Building the Shut-off Dam at the Charles River Basin." (Illustrated.)

October 20, 1909. — Gaetano Lanza and Lawrence S. Smith, " Comparison of the Results Obtained by the Use of Three Theories of the Distribution of the Stresses in Reinforced Concrete Beams, with the Experimental Results."

November 10, 1909. — (Informal.) T. Howard Barnes, " Some Observations on the Engineering Works, People and Conditions in Central America." (Illustrated.)

November 17, 1909. — Joseph H. O'Brien," Waterproofing of Engineering Structures "; and G. S. Vickery, " The Use of Manard Steel in Railroad Track." (Illustrated.)

December 8, 1909. — (Informal.) Charles T. Main and F. M. Gunby, " The Cost of Power for Various Industries under Ordinary Conditions."

December 15, 1909. — James W. Thomas, " An Account of the Tyng's Island Suspension Bridge near Lowell, Mass."; and R. R. Evans and George F. Swain, " The Old Chain Bridge at Newburyport, Mass."; and J. R. Worcester, " The Bellows Falls Arch Bridge." (All papers illustrated.)

January 5, 1910. — (Informal.) Edwin J. Beugler, " The Analysis of Water-Power Propositions." (Illustrated.)

January 21, 1910. — A joint meeting with the American Society of Mechanical Engineers and the American Institute of Electrical Engineers at Hotel Somerset, with speeches and discussion on a joint building for the engineering and other societies in Boston.

January 26, 1910. — Wm. L. Church, " Hydraulic Power Development with special reference to Ambursen Dam Construction." (Illustrated.)

February 9, 1910. — (Informal.) Lester W. Tucker, " Construction of the Gallatin Railway in Montana." (Illustrated.)

February 16, 1910. — Herman K. Higgins, " Progress at Panama." (Illustrated.)

The Sanitary Section of the Society has had four meetings during the year, with an average attendance of 49. It also made an excursion to Brockton on June 2, 1909, in which 25 took part.

The papers read at the meetings of the Section were:

March 3, 1909. — William S. Johnson, " The Volume of Sewage in Sewers Designed according to the Separate System."

October 6, 1909. — Alexis H. French, " The Brookline Sanitary Comfort Station "; Arthur D. Marble, " The Lawrence Sanitary Comfort Station."

December 1, 1909. — Earle B. Phelps, " Disinfection of Sewage by Means of Chemicals." George A. Johnson, " Disinfection of Water by Calcium Hypochlorite."

January 12, 1910. — William Gavin Taylor, " Design of Trickling Filters." O. M. Weand, " Construction and Operation of the Reading (Pa.) Sewage Disposal Works.

The Board of Government has held fifteen meetings during the year, one or more having been held each month, except the month of August.

On invitation of the American Society of Civil Engineers many members of the Boston Society of Civil Engineers attended the annual convention of the former society at Bretton Woods, N. H., during the week of July 5, 1909.

On July 11, 1909, such members of the American Society of Civil Engineers, with their ladies, as found it convenient to stop in Boston on their return from the convention, were entertained by members of the Boston Society of Civil Engineers in Boston, several automobile trips being arranged for their benefit.

At the special meeting held May 5, 1909, a description of the work on the Panama Canal was given by Mr. Frederic P. Stearns and Mr. Allen Hazen, members of a special engineering commission appointed by President Taft to visit the Isthmus. The attendance of this meeting was upwards of seven hundred, including ladies, and this may be recorded as the largest meeting in the history of the Society.

The Board commends the practice of appropriating as large a sum as can be spared for the purchase of books for the library and recommends that the sum of $50 be appropriated this year for that purpose.

The Board also recommends that a committee be appointed for the consideration of revisions of the By-Laws, which have been suggested at various times, regarding methods of election of officers, classification of members, adjustment of dues, etc.

At the last annual meeting of the Society the Board of Government was authorized to proceed with the project for a permanent home and to expend $125 000 for land and building. Later it was authorized to expend the permanent fund of the Society for this purpose as provided in the Constitution and By-Laws.

The formulation of a plan for such a home was referred to the Board and the Committee on Permanent Quarters, and several joint meetings were held early in the year. An appeal was also sent out by a special committee, requesting subscriptions to increase the permanent fund, and efforts made to enlist other associations in rental guarantees to the Society for rooms for their use. From the joint report of the Board and the Committee, which will be presented at this annual meeting, it will be seen that the results have not been very satisfactory; the matter was, therefore, held in abeyance during the summer.

Later a joint meeting and dinner were arranged by a committee of this Society acting with committees of the local members of the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, at which meeting the question of a joint club house and engineering building might be brought up.

This meeting and dinner was held on January 21, 1910, with an attendance of more than four hundred, and at the proper time the President of this Board introduced the subject with the result that the several engineering and kindred societies have been memorialized by the direction of those in attendance at that meeting, to appoint members to act on a joint committee to devise ways and means to establish and run such a club house and building as seems wise.

This Board on February 16, 1910, appointed as members of that joint committee, Messrs. George A. Kimball, Luzerne S. Cowles and Charles S. Clark.

The Board of Government looks forward to a report from the joint committee, which will result either in favorable joint action or a clear statement that such joint action is inadvisable, and feels that it has done all in its power during the year to bring this subject to a favorable conclusion.

For the Board of Government,

GEORGE B. FRANCIS, *President.*

ABSTRACT OF THE TREASURER'S AND SECRETARY'S REPORTS FOR THE YEAR 1909–1910.

CURRENT FUND.

Receipts:

Dues for 1909–1910	$4 269.00	
Dues for 1910–1911	46.00	
Dues for 1908–1909	17.00	
Rent of rooms	1 000.00	
Advertisements	865.00	
Library fines	3.50	
Sale of JOURNALS	6.50	
Balance on hand, March 17, 1909	721.69	
		$6 928.69

Expenditures:

Rent	$2 010.00	
Lighting	48.54	
Association of Engineering Societies	1 661.62	
Printing, postage and stationery	1 397.48	
Salaries	750.00	
Reporting meetings	152.50	
Stereopticon	135.00	
Books	83.00	
Binding	73.20	
Periodicals	36.50	
Repairs	8.75	
Advertisements in JOURNAL	15.00	
Incidentals	31.83	
Insurance	8.88	
Annual meeting	71.10	
Meeting, January 21, 1910	47.78	
Rent of drawer in vault	10.00	
		$6 541.18

Balance on hand, March 16, 1910	$387.51
Balance on hand, March 17, 1909	721.69
Excess of expenditures over receipts during year	$334.18

PERMANENT FUND.

Receipts:

Sixty-six entrance fees, Society	$660.00	
Two entrance fees, Sanitary Section	10.00	
Interest on deposits	203.07	
Interest on bonds	456.00	
Subscription to Building Fund	100.00	
Balance on hand, March 17, 1909	2 011.10	
		$3 440.17

Expenditures:

Merchants' Co-operative Bank, dues on shares	$300.00	
Volunteer Co-operative Bank, dues on shares	300.00	
Workingmen's Co-operative Bank, dues on shares,	300.00	
Franklin Savings Bank, deposit	20.48	
Warren Institution for Savings, deposit	30.74	
Boston Five Cents Savings Bank, deposit	29.56	
Provident Institution for Savings, deposit	25.29	
Eliot Five Cents Savings Bank, deposit	21.49	
Institution for Savings in Roxbury, deposit	20.07	
		1 047.63
Balance on hand, March 16, 1910		$2 392.54

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 16, 1910.

Twenty-five shares Merchants' Co-operative Bank	$3 779.67
Twenty-five shares Volunteer Co-operative Bank	4047.40
Twenty-five shares Workingmen's Co-operative Bank	1 195.88
Deposit in Franklin Savings Bank	527.62
Deposit in Warren Institution for Savings	792.51
Deposit in Boston Five Cents Savings Bank	742.08
Deposit in Provident Institution for Savings	761.61
Deposit in Eliot Five Cents Savings Bank	589.73
Deposit in Institution for Savings in Roxbury	550.60
Republican Valley Railroad Bond, 6%, par value	600.00
Boston Elevated Railway Bonds, 4½%, par value	4 000.00
C. B. & Q. Railroad Joint Bonds, 4%, par value	3 000.00
American Tel. & Tel. Co. Bonds, 4%, par value	3 000.00
Cash on deposit	2 392.54
Total Permanent Fund	$25 979.64
Amount of fund as per last annual report	24 141.25
Gain during the year	$1 838.39

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund	$25 979.64
Current Fund	387.51
Total	$26 367.15
Amount as per last annual report	24 862.94
Increase during year	$1 504.21

Report of the Committee on the Library.

The annual report of the Committee on the Library, which is herewith submitted, again emphasizes the fact that the walls of our rooms are still bulging outward.

The Library had the greatest accession year in the history of the Society, due to the gift of 304 volumes bound in cloth and a number in paper, all from the library of one of our former members, Mr. George Alanson Parker, who died in 1887; the gift being tendered by his son, one of our members, Mr. Harold Parker.

A special bookplate has been printed for insertion in these volumes which are not yet placed upon the shelves, due to lack of room. All of these volumes, although highly prized for the Library, are such as would not naturally fall into circulation, as few of them bear a later date than 1875, but they are of inestimable value in the history of the profession and its developments.

The Society owes a debt of gratitude to Mr. Harold Parker for his thoughtfulness in reserving these volumes for our Society. For the present they are stacked in the Library.

Aside from this gift, the Society has added 140 volumes bound in cloth and 122 in paper, 13 of those in cloth being the gift of Mr. Clemens Herschel, making a total in the Library, bound in cloth, of 6 585 volumes, without the Parker Library. Of these, 164 belong to the Herschel Library. It is possible by providing more shelf room and leaving the Parker Library undisturbed, to still house for several years more all books for which there would be any active demand, although always encroaching on the area desired for readers.

It may be wise, and this is offered as a suggestion from the Library Committee only, to engage one of the smaller rooms near our present quarters and on the same floor as an adjunct to our reading room. In this small room no books would be kept, but members might retire there for quiet study, as there is now no part of our Library where a reader may enjoy positive quiet.

During the year 193 volumes have been borrowed from the Library and $3.50 in fines have been collected.

Five book reviews have been written by members for the *Bulletin*, for which the thanks of the committee are tendered.

By arrangement with the McGraw-Hill Book Company 15 books, to the value of $40, have been acquired in exchange for advertising in the columns of the *Bulletin*.

A few odd volumes of magazines which seemed worth the expense have been bound in order to save them. Twenty-nine volumes of current magazines have also been bound.

A second plan-case should be bought to carry out the plan of properly caring for the Government Survey sheets which require much more room than they now have for convenient handling. The committee recommend that $30 be appropriated for this purpose and that $75 be appropriated for current engineering books during the coming year.

In addition to this the committee hopes that some member or members of the Society may feel moved to start a library endowment fund, of say $1 000, the income of which could be used to purchase current engineering books. the value or price of which appears to be rising every year.

Frederic I. Winslow,
J. M. Siner,
Henry T. Stiff,
Edwin R. Olin,
L. D. Thorpe,
Committee.

Report of the Board of Government and Committee on Permanent Quarters. (Abstract.)

To the Boston Society of Civil Engineers:

On February 17, 1909, the Committee on Larger Membership and Club House, in accordance with instructions previously received from the Society, reported four different studies for a permanent home or club house, of which No. 3 was for "a union club house, without cuisine, for the exclusive use of the several engineering and architectural societies whose headquarters are in Boston." (See report printed in both the Journal and the *Bulletin* for March, 1909.)

At the annual meeting, held on March 17, 1909, the matter was considered carefully and after full discussion the following vote was passed:

"*Voted:* That the Board of Government and the Committee on Quarters, with the Special Committee on Larger Membership and Club House, be requested to definitely formulate a plan along the lines of Scheme 3, and that the Board of Government be authorized to expend such funds to that end as may be required, it being understood that the cost of the proposed scheme should not exceed $125 000, including land and building."

On March 30, at a joint meeting of the Board and the committee, it was decided that the above scheme could be successfully financed without materially increasing the annual dues, provided the permanent fund could at once be increased by the sum of $50 000, and a special committee, consisting of Messrs. FitzGerald, Swain and Stearns, was appointed to canvass the Society for contributions. On April 26, this committee sent out an urgent appeal for subscriptions, calling attention to the fact that "a particularly favorable opportunity seems to present itself to secure at a moderate price a lot of land in a central situation with a four-story building which can be easily fitted to the requirements of the Society."

An effort was made to ascertain as accurately as possible the financial side of the problem. Various phases of the question were investigated by special committees; one as to the cost of preparing the house for occupancy and another upon the financial aspect of the scheme.

Owing to the impossibility of making any satisfactory arrangements with other societies and the fact that the initial subscriptions fell so far short of the sum fixed by the joint committee, no further action was taken.

While the amount raised was not sufficient to carry out the plans authorized under Scheme No. 3, the committee feels that its efforts have not been entirely without results. The interest felt by professional men in providing common headquarters, where all may unite for business or social purposes, is rapidly increasing. It is possible that the enthusiastic movement inaugurated at the recent Westinghouse dinner may result in some practicable plan and it is very desirable that a solution, satisfactory to the members of this Society, may be found without unreasonable delay.

In view of the possible results of this wider movement, your committee ask to be discharged.

For the Committee,

George B. Francis, *Chairman.*

Report of the Committee on Excursions.

To the Members of the Boston Society of Civil Engineers:

During the past year nine excursions have been made by the Society, as follows:

April 21, 1909. — To the Locomotive Terminal of the Boston & Albany Railroad at Allston, Mass., also to the new Freight Terminal at East Cambridge, Mass. Attendance, 23.

May 21, 22, 1909. — To the work under construction for the water department of the city of Springfield in the development of Little River. Attendance, 44.

June 16, 1909. — To the new Forest Hills Station of the Boston Elevated Railway and to the Cold Storage Plant of the Quincy Market Cold Storage and Warehouse Company. Attendance, 130.

September 15, 1909. — To the new Deep Water Terminal of the Boston & Albany Railroad at East Boston, Mass. Attendance, 27.

October 20, 1909. — To the Charles River Dam and other work of the Charles River Basin Commission at the Fenway. Attendance, 40.

November 17, 1909. — To the Works of the Metropolitan Park Commission along Mystic River and Alewife Park. Attendance, 7.

December 22, 1909. — To the Plant of the Coffin Valve Company at Neponset, Mass. Attendance, 30.

January 26, 1910. — To the work under construction on the Cambridge Main Street Subway. Attendance, 230.

February 16, 1910. — To the Plant of the American Waltham Watch Company. Attendance, including ladies, 60.

Total attendance, 591; average attendance, 66.

The committee has continued to compile information regarding new engineering work for publication in the *Monthly Bulletin* of the Society, and during the year 51 pages of this have been published, or an average of about $5\frac{2}{3}$ pages for each of the nine issues of the *Bulletin.* This feature of the *Monthly Bulletin* is increasing in importance, as can be seen from the total number of pages printed for each of the last four years, which have been respectively 36, $39\frac{1}{2}$, 43 and 51 pages. This has only been made possible by the coöperation of the members of the Society and others carrying on the work and the committee at this time wishes to extend its thanks to all who have thus contributed. It is hoped that such coöperation may be even more general in the future, as its publication helps to keep the members of the Society in touch with current engineering work and to make interest more general in the excursions.

Mr. H. L. Coburn, who was appointed a member of this committee, found it impossible to serve and this vacancy was filled by the appointment of Mr. Richard K. Hale.

The committee has a number of plans in the embryo which it will be glad to transmit to its successors.

There is a balance in the hands of the committee of $11.09.

Respectfully submitted,

H. K. Barrows, *Chairman.*
L. G. Morphy.
Richard K. Hale.
F. L. Murray.
Frank H. Carter, *Secretary*

Report of the Executive Committee of the Sanitary Section.

Boston, Mass., March 2, 1910.

At the annual meeting of the Sanitary Section, held March 3, 1909, the reports of the committees for the preceding year were placed on file. The committees on Rainfall and Run-Off, Collection and Tabulation of Sewerage Statistics, and Uniform Specifications for Sewer Pipe, respectively, were continued. The present membership of these committees is as follows:

On Rainfall and Run-Off: George A. Carpenter, chairman; H. K. Barrows, Lewis M. Hastings, Hector J. Hughes, William S. Johnson, Arthur T. Safford; Harrison P. Eddy, secretary.

On Collection and Tabulation of Sewerage Statistics: Harrison P. Eddy, chairman; Bertram Brewer, Charles Saville.

On Uniform Specifications for Sewer Pipe: Leonard Metcalf, chairman; E. S. Dorr, Charles R. Felton, Lewis D. Thorpe; F. A. Barbour, secretary.

On June 2 the Section made an excursion to Brockton and Silver Lake. The party arrived at Brockton and took motor carriages for the Sewage Disposal Works. After an inspection of the works the party was served a lunch through the courtesy of the Brockton Sewerage Commission, and conveyances were taken for Silver Lake, the source of the city's water supply. Here opportunity was given for viewing two large pumping engines, one in process of erection and nearly completed. Dinner was served and after an enjoyable out-of-doors day had been spent the members returned to Boston. About 25 were present.

The following papers have been read at regular and special meetings:

March 3, 1909. William S. Johnson, "The Volume of Sewage in Sewers Designed according to the Separate System."

October 6, 1909. Alexis H. French, "The Brookline Sanitary Comfort Station." Arthur D. Marble, "The Lawrence Sanitary Comfort Station."

These papers were amplified by Messrs. Harvey, Bunting and Humphries, who described plumbing fixtures which they had designed or had for sale.

The meeting was preceded by an excursion to Brookline.

December 1, 1909. Earle B. Phelps, "Disinfection of Sewage by Means of Chemicals." George A. Johnson, "Disinfection of Water by Calcium Hypochlorite."

January 12, 1910. William Gavin Taylor, "Design of Trickling Filters." O. M. Weand, "Construction and Operation of the Reading (Pa.) Sewage Disposal Works."

All of the papers were illustrated with lantern slides or diagrams and the discussions by the members have been full of interest.

The attendance at the meetings has been as follows:

Annual meeting	51
June excursion	25
October meeting	27
December meeting	69
January meeting	50

Exclusive of the June excursion the average attendance has been 49. The average attendance for the previous year was 45.

The additions to the membership of the Section are as follows:

By election. — March 3, 1909, Arthur Fuller Harkness.
October 6, 1909, Joseph Enright Conley.
October 6, 1909, Joseph B. Stewart, Jr.
December 1, 1909, Ralph J. Sherriff.
By enrolment from the Society. — December, 1909, Frank A. Marston.
January, 1910, James R. Baldwin.

An attempt has been made to increase the membership of the Section from among those city and town officials who have to do with the operation of sewerage systems. To this end letters have been written to several of these gentlemen, setting forth the advantages of the Section and the benefit which would follow the meeting together of town officers, superintendents and engineers.

We believe that so far as practicable the meetings should be devoted to those problems which arise in the practice of the sanitary arts, to the detailed methods for adapting the principles of hygiene and sanitary engineering to the every-day life of the community, rather than to the theoretical discussion of the principles exclusively.

For the Executive Committee,

Robert Spurr Weston, *Clerk.*

Report of Committee on Rainfall and Run-Off.

Boston, March 2, 1910.

Sanitary Section of the Boston Society of Civil Engineers:

Gentlemen, — Your committee has held several meetings during the year and has made an effort to increase the number of gaging stations at which measurements of rainfall and run-off are made. Two new stations have been established at New Bedford by the city engineer, Mr. Wm. F. Williams. Records have been kept at Cambridge, Lowell, New Bedford and Newton, Mass., Pawtucket, R. I., and Ithaca, N. Y. While many engineers have signified their interest in this subject, it appears to be very difficult for them to secure the necessary authority and appropriations to conduct such work. The committee has known of several instances where engineers have actually procured the necessary information about apparatus and presented the matter to proper authorities, but have failed to secure their approval and coöperation. While the lack of success in establishing new gaging stations has been somewhat discouraging, it is perhaps as well for the present that the work of the committee be confined to working up the data collected from existing stations.

In addition to the records collected at the gaging stations mentioned, data of similar gagings have been turned over to the committee by Mr. George S. Webster, Bureau of Surveys, Philadelphia, Penn., and Mr. Alexander J. Taylor, Engineer of Sewers, Street and Sewer Department, Wilmington, Del.

As is well known to all, the past summer — the season during which storms of maximum intensity are most likely to occur — was very dry and, consequently, only a few records have been obtained which are of interest in connection with this particular study. The committee now has in hand records of about fifty storms, although only a few of them

have been even partially worked up. The members have been very busy during the past year and, as the amount of time required for reducing the data to form convenient for study, comparison and tabulation, is large, the progress in this work has not been as great as was desired. It is believed, however, that the data collected have considerable value and only await collation to make them available for use.

It has become very evident to your committee that a long series of observations at each station will be necessary to obtain records of a sufficient number of typical storms to form a reliable basis for the design of storm water drains.

About a year ago the municipal engineers of the city of New York appointed a Committee upon Rainfall and Run-Off to make investigations similar to those being made by your committee. As soon as your committee learned of this action it sent a communication to the New York engineers, telling about the work which had been done in this part of the country, offering to coöperate with them and asking that they coöperate with us. In reply to this communication a very courteous note was received from the secretary, Mr. C. D. Pollock, stating that they would be most glad to coöperate with your committee in any possible way and expressing appreciation of the offer of your committee to coöperate with them. Since the passage of these notes several letters have been exchanged and much of the information regarding apparatus and methods which had been collected by your committee has been turned over to the New York engineers. No definite information is at hand as to the number of gaging stations established, or the amount of data collected by the New York committee, but it is felt that their work will supplement that of your committee and thus greatly increase the value of the work done.

While your committee appreciates that it has done only a small fraction of the work expected of it, and that the data in hand are of little value in their present condition, it believes that the work should be continued and prosecuted as much more vigorously in the future as may be possible.

Respectfully submitted,

Geo. A. Carpenter, *Chairman.*

Report of Committee on Uniform Specifications for Sewer Pipe.

Boston, Mass., March 2, 1910.

To the Sanitary Section of the Boston Society of Civil Engineers:

Gentlemen, — Your committee appointed to prepare standard specifications for vitrified sewer pipe begs to submit the following progress report. A final report, for reasons which will be set forth, is not yet advisable or possible. We are, however, convinced that standard specifications can be developed which will be of great value not only to the purchaser, but also to the manufacturer.

The factors of greatest importance in the standardizing of vitrified pipe are the thickness, — as it affects the strength, — the dimensions and shape of socket necessary for the making of tight joints, the nature of the material of which the pipe is made as it may determine depreciation, the character of the surface and the allowable variation from true circular section and longitudinal alignment.

A very limited consideration of the foregoing statement will indicate that standard specifications will probably result in increased cost of manufacture and that, therefore in order to make these specifications of any value the necessity for such changes from present conditions as appear advisable must be made very evident not only to the manufacturer, but to the purchaser of pipe. To make this plain a brief reference to the present conditions of manufacture and sale of this clay product may not be out of place. The making of vitrified pipe is not a strictly scientific process with a uniform and definite result. Whether necessarily so or not, the pipe differ greatly in quality when drawn from the kiln. Some are hard burned, straight and true in section with a good smooth surface; others are cracked, out of round and under-burned. Obviously, the manufacturer must work off as much of his product as first class as possible and, under present conditions with variable standards, he does manage to sell as firsts, in some sections of the country, pipe which in other sections would not be accepted. If standard specifications were generally adopted — and without such general acceptance they would be of little use — less pipe would pass as first class and, for such as might pass, a higher price would have to be obtained. It is, therefore, evident that the necessity for standard specifications must be made apparent to the purchaser and this can only be done by obtaining a general acceptance of these specifications by engineers all over the country.

Further, it is evident that the coöperation of the manufacturer, accorded willingly or forced by the pressure of a general demand for a more standard product, must be obtained in order to carry out such changes as would be required by standard specifications. Realizing this, your committee has made every effort to interest the manufacturers, but without any practical result other than to make plain that the pipe makers believe it to be more to their interest to continue to market their product under existing conditions than to coöperate in the development of standard specifications which would remove some of the present objections to vitrified pipe as a structural material. That there is room for improvement may be illustrated by brief reference to the present illogical relation of thickness to diameter in different sizes of pipe. Aside from the question as to whether any particular size is too thin or unnecessarily thick, it is no more than reasonable to expect that at least there should be some consistency. As a matter of fact, however, pipe from fifteen to twenty-four inches in diameter have not the same relative strength as the smaller or larger sizes, and it is between these limits where most of the breaks occur and where good practice now requires concrete reinforcement in all but the most favorable conditions of trench. Your committee believes that it will be distinctly to the advantage of manufacturers of vitrified pipe to have standard specifications developed which will be based on reasonable premises assuring consistency in relative strength and effecting as much simplification and uniformity as possible.

As already stated, however, the value of such specifications would rest on their general acceptance by engineers and it is obviously advisable for us to coöperate with other societies, so far as possible, in the development of these specifications. We believe it better, therefore, to postpone a final report and we have been led particularly to this conclusion because of the work being done by a committee, appointed with a similar object

by the American Society for Testing Materials, on which a member of this committee has a place. We hope, if continued, to reach conclusions acceptable to both committees and so obtain for the specifications which may be developed such a standing as will guarantee their general adoption by all engineers.

Respectfully submitted,

LEONARD METCALF, *Chairman.*
EDGAR S. DORR.
CHARLES R. FELTON.
LEWIS D. THORPE.
F. A. BARBOUR.

REPORT OF COMMITTEE ON UNIFORM SEWERAGE STATISTICS.

BOSTON, March 1, 1910.

SANITARY SECTION, BOSTON SOCIETY OF CIVIL ENGINEERS:

Gentlemen, — The Committee on Uniform Sewerage Statistics has continued its work during the past year and secured reports from 31 cities and towns for the year 1908, and 13 for the year 1909. This work has now been in progress during four years and returns have been made by 55 different municipalities, as follows: 23 for 1906; 24 additional, 1907; 6 additional, 1908; 2 additional, 1909.

Since its organization the committee has compiled statistics for two years, namely, 1906 and 1907, both of which summaries have been printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Efforts to obtain reports for 1909 have been confined to the New England States, not including Maine. The work was thus limited, because it was thought that on account of the proximity of the cities to Boston the interest of the officials might be greater in the work of the Section and that it was better policy to concentrate the work in this locality than to attempt to secure statistics from cities over the entire country. It is difficult to state what the result of this effort has been, because the number of reports thus far received is comparatively small, although it should be noted in this connection that the fiscal year has but just closed. Doubtless, considerable interest in this undertaking has been created by the greater effort made in this immediate locality and it is to be hoped that a larger number of summaries will appear in the annual reports of New England cities and towns.

As was pointed out in our last report, the greatest value of work of this kind appears to lie in the adoption by city officials of a systematic method of recording sewerage statistics and thus obtain statistics of their own departments, which must prove of particular value to them. In this connection it is interesting and important to note that the standard summary has been adopted and printed in the annual reports of the following fourteen cities and towns, all but one of which are located in New England:

Cambridge, Mass.	Newton, Mass.	Westfield, Mass.
Fitchburg, Mass.	North Adams, Mass.	Worcester, Mass.
Haverhill, Mass.	Plainfield, N. J.	Watertown, Mass.
Laconia, N. H.	Springfield, Mass.	Providence, R. I.
Lawrence, Mass.	Waltham, Mass.	

The committee now has in hand 31 reports for 1908 and 13 for 1909, which have not been fully compiled for publication, and the committee is in doubt as to the wisdom of attempting to publish this material. The expense of publishing the report and accompanying tables presented to the Section February 3, 1909, was approximately $320, and the advisability of expending this amount of money annually in publishing these statistics must be seriously considered by the Section.

The New England Water Works Association, which has for several years undertaken to publish periodically certain somewhat similar statistics bearing upon water works, has finally adopted the policy of publishing the data once in three years, and confines its compilations to such data as has been published in the annual reports of water-works officials. It is possible that some such arrangement might produce as good results as to continue the active solicitation of data for annual publication and at considerably less expense. The committee would suggest that this method be seriously considered by the Section.

Should the Section decide not to continue the effort to collect and publish data annually, the committee would suggest that the Clerk mail to the proper officials annually, on or about December 1, blank summaries to serve as a reminder that this data should be included in the annual reports.

The more general adoption of the standard summary would probably result from the admission to membership in this Section of a larger proportion of the engineers and superintendents having to do with sewer departments. The committee has turned over to the Clerk a list of the officials with whom it has been in correspondence, with a view to having an effort made to induce those who are not now members of the Section to join.

The effort to collect sewerage statistics has always met with very cordial support on the part of many sewer officials, and the committee desires to take this opportunity of expressing its appreciation for the assistance which has thus been rendered it.

Respectfully submitted,

HARRISON P. EDDY,
BERTRAM BREWER,
Committee.

Civil Engineers' Society of St. Paul, Minn.

ST. PAUL, MINN., March 14, 1910. — A regular meeting of the Civil Engineers' Society of St. Paul was held in the Society's room in the Old State Capitol Building at 8 o'clock P.M., with Vice-President L. P. Wolff in the chair; seven members were present.

The minutes of the previous meeting were read and approved.

The applications of Charles. H. Hickman and Edward J. Dugan for full membership in the Society were read; and upon motion, duly seconded, it was carried that the Secretary cast the ballot of the Society, electing these applicants as petitioned.

Moved, seconded and carried that article No. xvii of the Constitution be amended to read: " Resident membership shall be applied to all mem-

bers residing within the corporate limits of the cities of St. Paul and Minneapolis in Minnesota. Non-resident membership shall apply to those who reside outside of the above said limits." The Secretary was instructed to advise all members immediately by letter, that this amendment would be voted upon at the next regular meeting of the Society, which will be held on Monday evening, April 11, 1910.

The resignation of Mr. H. H. Harrison, of Stillwater, Minn., was read and, upon motion duly seconded, the Secretary was directed to write Mr. Harrison of the Society's intention of altering the present status of resident and non-resident membership, with the idea of having Mr. Harrison reconsider his resignation.

A communication from the Engineers' Club of St. Louis, with reference to a certain bill before our Congress, which purports to define the standing of civilian engineers in the United States Army, together with a set of resolutions adopted by that club and pertaining to the subject matter under consideration, was read and ordered placed in the hands of a committee, composed of DuShane, Pomeroy, Meyers and Van Ornum, with instructions to report their conclusions to the Society at its next regular meeting.

A communication from the Chicago Association of Commerce, inviting this Society to participate in their exposition to be held in Chicago in September and October, 1911, was read and placed in the hands of a committee composed of Messrs. Starkey and Palmer, with instruction to ascertain from the St. Paul city officials what this city's plans were with reference thereto and to report their findings to the Society at its next regular meeting.

There being no further business the meeting adjourned.

D. F. Jurgensen. *Secretary.*

Association of Engineering Societies.

Vol. XLIV. **APRIL, 1910.** No. 4.

PROCEEDINGS.

Civil Engineers' Society of St. Paul.

St. Paul, Minn., April 11, 1910. — The fourth regular meeting of the year was held in the Society's room at the Old State Capitol Building at 8 o'clock p.m. with President J. D. DuShane in the chair. There were present seven members.

The minutes of the previous meeting were read and approved. The matter of amending Article 17 of the constitution, by which it was proposed to define the status of resident and non-resident members, was ordered laid on the table, and upon motion duly seconded it was carried that this proposed amendment be submitted to all members for a written ballot; the Secretary was ordered to prepare such a ballot immediately.

The committee having in hand the subject-matter of a certain bill, H. R. 7117, pending before Congress concerning the status of civilian engineers in the United States Army reported their conclusions and recommendations to the Society, upon which the following resolution was adopted:

"*Resolved*, That we, the Civil Engineers' Society of St. Paul, Minn., believing that H. R. 7117, a bill to increase the efficiency of the Engineer Corps of the United States Army, does not offer better opportunities to civilian engineers entering the government service, or greater inducements for able assistant engineers now in the service to remain, or add to the efficient and economical conduct of our public works, do hereby express our disapproval of said bill as at present constituted, and further express our judgment that in the present form it should not become a law.

"We do, however, recommend and urge that the pending bill, H. R. 7117, be modified and amended to the end that civilian engineers be entitled to the same emoluments, rank and tenure of office as engineer officers in the army of equal qualifications."

The Secretary was ordered to send a copy of above resolution to Hon. Knute Nelson, Hon. Moses E. Clapp and Hon. F. C. Stevens, and also to all the societies comprising the Association of Engineering Societies.

The resignation of Geo. L. Wilson was read and accepted.

There being no further business, the meeting adjourned.

D. F. Jürgensen, *Secretary*.

Montana Society of Engineers.

Butte, Mont., March 12, 1910. — The regular meeting for the current month was held on the above date with Vice-President McArthur in the chair. After the reading and approval of the minutes of the February meeting, Mr. Will S. Hartman was elected to junior membership in the Society. The application of William A. Kemper for membership was read, approved and the usual procedure ordered. The trustees reported, regarding a search for better quarters for the Society, to the effect that while they had a favorable opinion concerning one place, they had not been able to secure a definite rental price and for that reason were given further time. No report concerning the Society Journal was presented. The resolutions committee on the death of our late member, E. C. Kinney, were given one month in which to prepare their report. The Secretary read some resolutions of the Engineers' Club of St. Louis concerning pending congressional legislation on Bill H. R. 7117, and the same were ordered placed on file. Mr. C. W. Goodale, of the State Road Committee, read considerable correspondence from President F. M. Smith regarding the state road project and the prospective " Good Roads Convention " to be held in Billings next June, and after the reading an animated discussion of the topic followed in which nearly every member present took part. The committee expressed the wish that all members of the Society, wherever residing, would take part in the movement and assist the committee by the expression of their views by letter and in any way possible. The discussion was continued to the April meeting. Adjournment followed.

Clinton H. Moore, *Secretary.*

Association
of
Engineering Societies.

Vol. XLIV. **MAY, 1910.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, March 2, 1910. — The 682d meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, March 2, 1910, at 8.30 o'clock. President Holman presided. There was a total of 96 present, many of whom were ladies.

The minutes of the 681st meeting were read and approved and the minutes of the 476th meeting of the Executive Committee were read.

The following gentlemen were elected to membership: John Anderson, Frank G. Jonah.

The following applications were read: For membership: Joseph G. Frost, George B. Evans. For associate membership: Barney H. Sanders, George G. Prendergast. For junior membership: Wm. D. Barnes.

The address of the evening was then presented by Mr. T. Kennard Thomson, Consulting Engineer of New York City, who spoke on the subject of " Foundations for Buildings and Bridges, showing Men working in Compressed Air." The address was liberally illustrated with an excellent set of lantern slides, showing the development of the caisson method from its first applications to the most recent work of this kind. The illustrations were drawn from a great variety of different bridges and especially from deep foundation work for the skyscrapers of New York City.

At the conclusion of the address a unanimous vote of thanks was tendered Mr. Thomson for his kindness in making the trip to St. Louis and for his excellent address.

The meeting then adjourned to the adjoining rooms, where the Entertainment Committee had provided refreshments.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, March 16, 1910. — The 683d meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, March 16, 1910, at 8.30 p.m., President Holman presiding. There were present 19 members and 6 visitors.

The minutes of the 682d meeting were read and approved and the minutes of the 477th meeting of the Executive Committee were read in abstract.

An application for membership was read from Mr. E. H. Tenney.

The following gentlemen were elected: George B. Evans, member; Joseph G. Frost, member; B. H. Sanders, associate member; George G. Prendergast, associate member; William D. Barnes, junior member.

The paper of the evening, on "A Theoretical Formula for the Curve Resistance to the Flow of Liquids," was then presented by the author, Mr. Philip J. Markmann. The paper was too long and mathematical for adequate abstracting, but in general a formula was derived, the results of which were then compared with certain experiments conducted in Detroit, and which are to be found in the transactions of the American Society of Civil Engineers.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, April 9, 1910. — By special action of the Executive Committee, the 684th meeting of the Club was held jointly with the American Society of Mechanical Engineers and the St. Louis Section of the American Institute of Electrical Engineers, on Saturday evening, April 9, 1910. By virtue of his membership in all three societies, President Holman of the Engineers' Club presided. The total registered attendance was 86.

By general consent all special business of the individual coöperating societies was postponed.

The following papers were presented in abstract: "Economy of the Electric Drive in the Machine Shop," by Mr. A. L. DeLeeuw of the Cincinnati Milling Machine Company, abstracted by Prof. E. L. Ohle. "Electric Driving," by Mr. Charles Robbins of the Westinghouse Electric and Manufacturing Company, abstracted by Mr. F. A. Berger. "Motor Application to Machine Tools," by Mr. Charles Fair of the General Electric Company, abstracted by Prof. A. S. Langsdorf. "Mechanical Features of Electric Driving," by Mr. John Riddell, abstracted by Mr. O. Stephensen.

The discussion of these papers was participated in by Dean Goss, of the University of Illinois, Messrs. E. R. Fish, A. H. Timmerman, P. A. Morse, —— Beardsley, H. W. Hibbard, H. H. Humphrey, O. Stephensen, Wm. H. Bryan and A. S. Langsdorf.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, April 20, 1910. — The 685th meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, April 20, at 8.30 o'clock, President Holman presiding. The attendance consisted of 30 members and 5 visitors.

The minutes of the 683d and 684th meetings were read and approved, and the minutes of the 478th meeting of the Executive Committee were read. The Secretary read a letter from the Secretary of the National Rivers and Harbors Congress, requesting that the Engineers'

Club take out membership. The latter was accompanied by a note from Col. J. A. Ockerson, stating that in his opinion the aims of the Club did not cover participation in the work of the Congress and, in the absence of any special action, the letter was ordered filed. A letter was also read from the officers of the Conventions Bureau of the city of St. Louis, in which the request was made that the Club take out ten annual certificates of membership and that each individual member of the Club also take out an annual membership. On motion, duly seconded, it was voted that the matter be laid on the table.

Mr. Edward H. Tenney was elected to membership. An application for membership from Mr. Edward P. Evers was read.

The paper of the evening, on "The Work of the Weather Bureau and its Relation to Engineering," was then presented by Mr. J. Warren Smith, in charge of the local office of the United States Weather Bureau. Mr. Smith presented in a most interesting manner the details of the work now in progress in the Bureau, which has as its object the coördination and publication of information concerning rainfall, snowfall, evaporation, wind and temperature conditions, and river gaging in various districts of the United States, these data being arranged in such a manner that the hydrographic data pertaining to any particular drainage district may be found in a single report. The object of the work is to furnish engineers with complete information necessary in irrigation work, and in hydraulic problems in general. A large number of lantern slides was shown, illustrating the instruments used in the work of the Bureau, typical weather charts, details of observatories, and photographs of cloud, hail and snow formation.

At the conclusion of the address an interesting discussion was participated in by a considerable number of the members present, and a unanimous vote of thanks was tendered to Mr. Smith for his courtesy in addressing the Club.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, April 20, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Lorimer Hall, Tremont Temple, at 7.45 o'clock P.M., President Henry F. Bryant in the chair. Over three hundred members and visitors present, including ladies. The members of the American Society of Mechanical Engineers and of the Boston Section of the American Institute of Electrical Engineers coöperated with the Society in the meeting.

The record of the annual meeting as printed in the April *Bulletin* was approved.

Messrs. Chester S. Allen, Charles L. Brown, Alfred O. Doane, Harry R. Draper, Frederick C. H. Eichorn, Charles Freed, James B. Flaws, George A. Sampson and David Sutton were elected members of the Society.

The Secretary reported for the Board of Government that under authority of the vote passed at the annual meeting, referring to the

Board with full powers, the question of appointing the special committees of the Society and the selection of members thereof, the following committees had been appointed:

On Excursions: F. H. Carter, R. K. Hale, T. W. Norcross, G. E. Howe and H. K. Higgins.

On the Library: F. I. Winslow, H. T. Stiff, E. R. Olin, J. N. Siner and G. V. White.

On Revision of Constitution and By-Laws: J. R. Worcester, S. E. Tinkham, G. A. Carpenter, C. R. Gow, W. S. Johnson and Leonard Metcalf.

On Joint Committee on Club House: G. A. Kimball, L. S. Cowles and C. S. Clark.

The Board also appointed the following to represent the Society on the Board of Managers of the Association of Engineering Societies, in addition to the Secretary, who is *ex officio* a member: Dexter Brackett, C. W. Sherman, G. A. Kimball, H. P. Eddy, A. T. Safford and J. R. Worcester.

The Secretary also presented and read the report of the Board submitting resolutions in relation to the work of the Corps of Engineers, U. S. Army. After the adoption of an amendment offered by Mr. Howland, the report was accepted and the resolutions were adopted in the following form, two thirds of the members present voting in the affirmative:

Whereas, The river and harbor work of our country has grown to such proportions and importance as to necessitate an enlargement of the corps of engineers, and

Whereas, A bill, H. R. 7117, introduced April 12, 1909, has been recently reported by the Committee on Rivers and Harbors of the House of Representatives, providing for an increase in the number of officers comprising the Corps of Engineers of the U. S. Army and defining the conditions under which civilian engineers may become eligible for appointment, and

Whereas, The best interest of the government would be served by placing the engineering work in charge of the most competent engineers available, and

Whereas, While we recognize the excellent record of the corps of engineers for faithful and devoted service in connection with public works, we also realize the increasing importance of the civil work under their charge, the development of engineering education and practice in our country during the past twenty-five years and the increasing number of civil engineers who have been specially trained to direct large public undertakings:

Therefore, be it resolved,

First. That the Boston Society of Civil Engineers favors and urges the passage of such laws by Congress as will facilitate the assignment of trained civil engineers to direct civil engineering work conducted by the Corps of Engineers.

Second. That such engineers should have the same relative rank and pay as officers of the Corps of Engineers of the U. S. Army holding similar assignments.

Third. That neither assistant engineers nor officers of the Corps of Engineers should be detailed in charge of river and harbor districts or

divisions until they have had at least five years' experience on works of engineering construction.

Fourth. That the opportunity for the promotion of civil engineers to positions of authority should be widened.

Fifth. That copies of these resolutions be sent to the Committee on Military Affairs, to the Committee on Rivers and Harbors of the House of Representatives, the corresponding committees of the Senate and the Senators and Representatives from the New England states, and the chief of engineers of the U. S. Army.

The President announced that under Article V of the Constitution the resolutions must be adopted at the next regular meeting before they would be operative.

The Secretary submitted the following report for the Board of Government:

Boston, Mass., April 20, 1910.

To the Boston Society of Civil Engineers:

At the annual meeting on March 16, 1910, it was voted to request the Board of Government to consider the subjects of increase in annual dues and additional grades of membership and to report to the Society.

After due consideration the Board recommends that certain changes be made in the Constitution and By-Laws in order to provide for an additional grade of membership and an increase in annual dues.

The additional grade suggested is that of junior member with minimum age of eighteen years and a maximum age of twenty-five years and without the privilege of voting. On reaching the age of twenty-six, the junior member should automatically become a candidate for full membership and, if elected, should pay the balance of the full entrance fee, or be dropped from the rolls.

This new grade is one which is found in the majority of engineering societies and meets a demand which is frequently voiced by our members and by prospective members. Such a grade is believed to raise the standard of full membership and as likely to increase the number and therefore the interest of the younger men.

Regarding the proposed increase in dues, we are confronted on one side by the natural preference for a minimum sum and on the other by the various appropriations which with ordinary and necessary current expenditures produce an apparent deficit for the year. Such a deficit existed last year, but was met by the surplus from previous years. This year it is probable that the deficit will be real unless an unexpected amount of advertising should relieve the situation.

The strong feeling existing for new quarters in the proposed Society house, the desire for an independent journal as manifested by the vote at the annual meeting, and the natural and proper expansion of our activities, all indicate that the time has arrived for a readjustment of the annual dues.

The following schedule shows both existing and proposed dues and grades which compare very favorably with those shown in a table compiled by the Secretary showing grades and dues for other societies.

Grades and Fees Proposed for the Boston Society of Civil Engineers.

		Annual Dues.			
		Resident.		Non-Resident.	
Grade.	Entrance fee.	Present.	Proposed.	Present.	Proposed.
Members,	$10 00	$8 00	$10 00	$5 00	$6 00
Honorary Members,	—		—		—
Associates,	10 00	8 00	10 00	5 00	6 00
Junior Members,	5 00	—	5 00	—	3 00

It is also recommended that the practice of abating first year dues

of new members be discontinued and that future members of sections shall be one of the four grades given above.

For the Board of Government,

S. E. TINKHAM, *Secretary.*

On motion duly made and seconded, it was voted: That the report of the Board of Government on additional grades of membership and increase of dues is hereby accepted, and is referred to the Committee on Revision of Constitution and By-Laws.

The President announced the death of Past President George Leonard Vose, which occurred on March 30, 1910, and, on motion, the President was requested to appoint a committee to prepare a memoir. The committee appointed consists of Messrs. Alfred E. Burton and George F. Swain.

On motion of Mr. Chase the thanks of the Society were voted to the officials of the American Sugar Refinery Company, for courtesies shown members of the Society this afternoon on the occasion of the visit to the works of that company.

Mr. Frederick H. Newell, of Washington, D. C., Director of the U. S. Reclamation Service, then gave a very interesting lecture on the "Engineering Work of the Reclamation Service." The lecture was profusely illustrated by lantern slides showing the proposed reservations and the various irrigation works with which the Service has been connected, speaking especially of the Roosevelt Dam, the Yuma Dam, the Gunnison Tunnel, Jackson Lake, the Boise River and Yellowstone, Truckee, Missouri, North Platte and Shoshone enterprises.

Adjourned.

S. E. TINKHAM, *Secretary.*

SANITARY SECTION.

A special meeting of the Sanitary Section, Boston Society of Civil Engineers, was held on Wednesday evening, May 4, at the Boston City Club.

Mr. John H. Gregory described the new sewage disposal plant at Columbus, Ohio, illustrating his talk with lantern slides.

Mr. Gregory used as the basis for his talk the article written by him for the American Society of Civil Engineers, but giving special attention to the more important phases of the work. There were several interesting facts brought out by the paper and discussion. Thus, it has appeared in the operation of the works that the septic tanks are probably not a necessary feature, and that plain sedimentation tanks would be as serviceable. One detail which escaped notice in the original designs was provision for taking care of leaves blowing into the septic tanks during the fall of the year. This matter caused some little trouble for a time and was solved temporarily by additional screens in the division chamber just before the effluent from the septic tanks goes to the sprinkling filters.

The paper was discussed by several members of the section and was of especial interest from Mr. Gregory's intimate association with this work from its beginning, he being directly in charge of both the office and field work.

Forty-five members of the section were present.

H. K. BARROWS, *Clerk.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., May 9, 1910. — The fifth regular meeting of the year was held in the Society's rooms at the Old State Capitol Building at 8 o'clock P.M., with President J. D. DuShane in the chair. There were present ten members and two visitors.

The minutes of the previous meeting were read and approved.

Letters replying to the Society's resolutions and bearing upon the Young bill (H. R. 7117) now pending before Congress, from Hon. Knute Nelson and Moses E Clapp, U. S. Senators from Minnesota, and Hon. F. C. Stevens, member of Congress from this the 4th Congressional district of Minnesota, were read and ordered filed.

The written motion from non-resident member K. W. Tanner, of Webster, So. Dak., and reading as follows: "Any member living within fifty miles from the city of St. Paul, Minn., who wishes to remain or to become a resident member, may by applying to the Board of Government be granted such a privilege," was declared in order; after a spirited discussion it was decided that such an amendment would be a superfluity, as the proposed amendment to Article XVII of the Constitution now before the Society and upon which a written ballot was ordered does not abridge this particular privilege in any way; so it was regularly moved, seconded and carried that Mr. K. W. Tanner's motion be tabled.

A committee of two, comprising Messrs. Starkey and Armstrong, were appointed to arrange for an automobile trip, to some point of engineering interest, for the Society during the summer vacation at a date to be fixed later by the committee.

Mr. J. D. DuShane was appointed a committee of one to arrange for a steamboat trip for the Society, to inspect the deepening of the channel of the Mississippi River near Hastings, at a date to be fixed later.

There being no further business to engage the attention of the Society the meeting adjourned to Monday evening, October 10, 1910.

D. F. Jürgensen, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, April 29, 1910. — Regular meeting called to order at 8.30 o'clock P.M., in the Kohler and Chase Hall, 24 O'Farrell Street, by President Dickie.

About two hundred, members and friends, were present.

The President ordered that the reading of the minutes of the last regular meeting be dispensed with and introduced the lecturer of the evening, Mr. Hermann Schussler, who addressed the Society on the subject of the "Water Supply of San Francisco." Mr. Schussler displayed detailed maps to illustrate the situation. He showed by diagrams and curves the growth of population, the growing daily consumption and the methods by which the supply had been augmented from time to time to satisfy the increasing demand.

He showed that from available sources the daily supply could be gradually increased from 35 000 000 to 110 000 000 gal. and that this would satisfy the growing population for probably forty years.

He illustrated his lecture with many interesting lantern slides showing construction and completed work, as well as pictures of the watersheds of existing and contemplated storage reservoirs.

Upon completion of this instructive lecture it was moved that a vote of thanks be tendered Mr. Schussler for the courtesy in addressing the members of the Technical Society on a subject of such vital importance to the city of San Francisco.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

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PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 4, 1910. — The 686th meeting of the Engineers' Club of St. Louis was held in the Club rooms on Wednesday evening, May 4, at 8.30 o'clock, Vice-President Von Maur presiding. There were present twenty-seven members and three visitors.

The minutes of the 685th meeting were read and approved, and the minutes of the 479th meeting of the Executive Committee were read. Mr. Edward P. Evers was elected to membership. On motion of Mr. Flad, it was voted that a committee be appointed to confer with the officials of the Public Library for the purpose of inducing those officials to increase the collection of technical books.

There being no further business, the paper of the evening, by Mr. Oddgeir Stephensen, on " Some Comparisons of American and European Methods in Engineering Education," was presented. Mr. Stephensen handled the subject in a very interesting manner, one of the chief points made being that American technical schools are handicapped to a greater extent than are similar European institutions by the less complete degree of preparation of the entering students. The discussion that followed was participated in by Messrs. Colnon, Langsdorf, Schuyler, Timmerman, Von Maur, Rohwer, Metzger, Flad and Rolfe.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, May 18, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M.

President Henry F. Bryant in the chair, ninety-two members and visitors present.

The reading of the record of the April meeting was dispensed with and the record as printed in the May *Bulletin* was approved.

Messrs. John W. Bickford, Frank H. Dillaby, William J. Dotten, Joseph Driscoll, Charles H. Eglee, Howard L. Farwell, Raymond W. Ferris, Hubert W. Flaherty, Leroy P. Henderson, Henry M. Johnson, James A. Lockhart, Raymond W. Parlin, George E. Russell, James C. Scorgie, George P. Soutar, Ralph E. Tarbett and William O. Wellington were elected members of the Society.

The Secretary read communications from the Civil Engineers' Society of St. Paul, Minn., and from the Louisiana Engineering Society, transmitting resolutions passed by these societies in relation to bills now pending before Congress concerning the status of civilian engineers in the U. S. Army. On motion of Mr. Thompson, the Secretary was directed to acknowledge the receipt of the communications and transmit to these societies the actions taken by this Society.

The communication from the Louisiana Engineering Society also contained resolutions advocating the City of New Orleans as "the logical point at which to hold a Universal Exposition in 1915, in celebration of the opening of the Panama Canal," and urging this Society to adopt similar resolutions. On motion of Mr. Johnson, it was voted to lay these resolutions on the table.

The consideration of the resolutions in relation to the work of the Corps of Engineers, U. S. Army, passed at the last meeting and printed in the May *Bulletin* with the minutes of that meeting, was then taken up. After a discussion by Mr. A. H. Howland of the advisability of passing the resolution and the defeat of a motion to indefinitely postpone action, the resolutions were adopted by a rising vote, 47 members voting in the affirmative and 1 in the negative.

The time for the literary exercises having arrived, as required by the By-Laws, the President introduced Mr. Luis G. Morphy, who gave a very interesting description of the East Boston Deep Water Terminals of the Boston & Albany Railroad Company, which was very fully illustreatd by lantern slides. Mr. John B. Russell, who was a resident engineer on the work, followed, with some interesting details.

The business of the meeting was then resumed. Mr. J. R. Worcester, chairman of the Committee on Revision of the Constitution and By-Laws, submitted the report of that committee as printed and sent out with the May *Bulletin*.

Mr. Worcester moved that the amendments, as printed, be adopted. Pending the consideration of this motion, on motion of Mr. Weston, the Society voted to adjourn to next Wednesday evening at the Society rooms for the discussion of the proposed amendments.

S. E. Tinkham, *Secretary*.

Boston, May 25, 1910. — Pursuant to an adjournment of the regular May meeting, the Society met this evening at 7.45 o'clock in its rooms, 715 Tremont Temple.

President Henry F. Bryant in the chair, twenty-two members being present.

The President announced that the motion before the meeting at the time of adjournment was on the adoption of the amendments to the Constitution and By-Laws as reported by the committee.

On motion of Mr. Higgins, the Society resolved itself into a Committee of the Whole for the consideration of the revision of the Constitution and By-Laws.

At 9.20 o'clock the committee rose and reported back a draft of a revised Constitution. On motion of Mr. Worcester, it was voted to adopt the Constitution as reported by the Committee of the Whole, eighteen members voting in the affirmative and one in the negative. The Constitution, as adopted, is sent with the June *Bulletin*.

The meeting again resolved itself into a Committee of the Whole for the consideration of the proposed changes in the By-Laws.

At 10.50 o'clock the committee rose and reported to the Society a new code of By-Laws. On motion of Mr. Worcester, it was voted to accept the report of the Committee of the Whole.

The report of the committee is sent with the June *Bulletin*.

At 10.55 o'clock it was voted to adjourn.

S. E. Tinkham, *Secretary*.

Sanitary Section.

The June Excursion of the Sanitary Section, Boston Society of Civil Engineers, was made on June 1 to Hudson, Mass., where the party visited the wool scouring waste disposal plant of the Hudson Worsted Company, also going through the mill itself. A special car was then taken to the municipal sewage disposal plant of the town of Hudson and some time spent in looking this over.

The train was then taken to Wayside Inn, where dinner was served and the regular meeting of the Section held. At this meeting it was voted as follows:

"To extend to the Hudson Worsted Company, to the Commissioners of Public Works of the Town of Hudson, and to the Boston & Maine Railroad, the thanks of the Section for courtesies extended on the occasion of the excursion of the Section on June 1, 1910."

The party returned to Boston, reaching there about five o'clock.

About twenty-five members participated in this excursion and it was thoroughly enjoyed by all, especially the afternoon at Wayside Inn.

H. K. Barrows, *Clerk*.

Utah Society of Engineers.

Meeting held in Society Headquarters, Newhouse Building, April 20, 1910. — Minutes of previous meeting and of last meeting of the Executive Committee read and approved.

The annual reports of the Treasurer and Secretary were read and upon motion accepted and spread upon the records.

Resolutions from the Engineers' Club of St. Louis regarding the status of civilian engineers engaged upon government work were read and action deferred until next meeting.

The application for membership of Mr. Dale Pitt was received and, upon ballot, Mr. Pitt was unanimously elected.

Mr. E.W. Newcome, signal engineer of the Oregon Short Line Railroad, presented an extremely interesting paper on "Signal Engineering," which was illustrated by numerous lantern slides and diagrams. Mr. Newcome traced the development of railway signaling, and gave an interesting description of the various systems in the order of their introduction, considering the telephone and telegraphic dispatching system, the manual control, block signal system, the manual control and track circuit system, electrical staff system, automatic block signal system, and gave also a brief but interesting description of interlocking, both manual, electrical and electropneumatic.

Dr. Merrill, after expressing the thanks of the Executive Committee to Mr. Newcome, introduced Mr. O. A. Honnold, the newly elected President for the ensuing year, who briefly outlined the policy for the coming year. Remarks were also requested from Messrs. William Ashton, B. F. Tibby, C. H. Repath and Dr. Lyman.

Announcement was made that, as a result of letter ballots on the proposed amendment to the Constitution, increasing the initiation fee to $5.00, the amendment had been carried.

Meeting adjourned.

H. C. Hoyt, *Secretary.*